QUALITY EVALUATION AND CATTLE GRAZING BEHAVIOR ON BAHIAGRASS AND LIMPOGRASS PASTURES

BY

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TO

CID, MYRTHES and BEATRIZ (in memory)

KEPLER

RAYANNE, RAYSLA and IGOR

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Abstract of Dissertation Presented to the Graduate School
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BY

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A continuous grazing experiment was conducted from June to October, 1982, to study changes in sward characteristics of Floralta limpograss (Hemarthria altissima) and Pensacola bahiagrass (Paspalum notatum) over the season, effects of sward changes on eating behavior components of grazing steers, and to relate eating behavior to intake and steer performance.

Nutritive value of both species decreased over the grazing season. The general trend was an increased crude protein content and in vitro digestibility from basal to top layers. Throughout the grazing season, both species tended to decrease in bulk density of organic matter, leaf blade, leaf sheath, stem and dead matter from basal to top layers. Organic matter on offer for both species accumulated at a decreasing rate over the grazing season; however, the two species differed in total forage on offer and in seasonal variation in gradient distribution of plant components. Floralta limpograss had higher green:dead matter and lower leaf blade:stem ratios.

Steers on both species had similar average daily gains and estimated intakes were similar for both species. Steers grazing both species showed preference for green herbage and leaf. Diet selected by steers was higher in crude protein and in vitro digestibility than total material on offer in the sward. To maintain level of intake of both species as the grazing season progressed, steers increased total number of bites. This compensation was effective only in early stages of the grazing season, since total bites and intake decreased in late season. Steers on Floralta limpograss had a larger bite size and those on Pensacola bahiagrass had more bites per day. Bite size was the major factor influencing estimated herbage intake. Use of two or more sward components in combination explained most of the variation in eating behavior components, estimated intake, and live weight gain.

Estimated intake based on eating behavior components did not provide accurate absolute values; however, they did provide a useful basis for explaining effects of variation in sward characteristics on changes in herbage intake over the grazing season.

CHAPTER 1
INTRODUCTION

In a world where population increase and food shortage are the dominant problems, the consumption of cereal grains by animals can be competitive with man. However, animals should not be divorced from man's food supply, especially the ruminant animal which is particularly valuable because of its ability to utilize forages and by-products which cannot be used directly in human nutrition.

More than 50% of the world's land area is unsuited for tillage and, therefore, for crop production. Such land could be used to produce animal protein through grazing ruminants. Thus, forages can make an important contribution to future world food supply by providing greater amounts of meat and dairy products at acceptable prices. However, the achievement of animal production goals in the absence or near absence of the use of concentrate feedstuffs will require additional research to improve the quality of forages and forage utilization.

Intake of digestible nutrients is the major factor which determines the level of animal production from pastures. Although studies with cut forages fed to penned animals have provided information on many factors limiting intake of grazing animals, there are additional factors which are unique to the pasture-animal interface such as pasture yield, sward structure and relative proportions of components such as dead matter, green leaf and stem which affect ease of harvesting and selection by the animal.

In spite of intensive research during past years, techniques for precise estimation of intake by grazing animals have not yet been developed. Intake of herbage by grazing animals can be estimated as the product of time spent grazing, rate of biting during grazing, and herbage intake per bite. Moreover, descriptions of distribution of plant components within the sward and their association with measurements of the components of eating behavior have been providing valuable understanding of factors influencing herbage intake by grazing animals and suggesting advantageous means of controlling this intake.

This research was conducted with the objectives to study changes during the grazing season in sward characteristics of two dissimilar tropical grasses and the eating behavior components of animals grazing these swards, and to relate changes in sward character to eating behavior components, animal performance, and diet selection by the animal.

CHAPTER 2
LITERATURE REVIEW

Characteristics of Paspalum notatum and Hemarthria altissima

Paspalum notatum, Flugge (Pensacola bahiagrass), is a perennial tropical grass with stolons and rhizomes; the stolons are firmly pressed to the ground, have numerous very short internodes and root freely from nodes, which also develop leaves and shoots. Fertile stems are two or four noded and are 15 to 70 cm, and occasionally 100 cm, high. Leaves are 5 to 20 cm, sometimes 50 cm long and 2 to 10 mm wide. The inflorescence is a racemose panicle bearing two or sometimes three racemes. Bahiagrass forms a dense cover and is valued for its productivity, relative ease of establishment and persistence (Bogdan, 1977). Bahiagrass has a growing point located close to the soil surface and, over the growing season, more than 80% of the forage produced is leaves (Beaty et al., 1968). This grass flowers in the early summer and flowering is hastened by warm temperatures (Humphreys, 1978). It withstands drought, soil with low fertility levels (Beaty et al., 1960; Jones, 1971) and some degree of frost (Jones, 1969). Quality of the forage is highest in early spring, but by midsummer it is extremely fibrous, unpalatable and low in nutritive value

(Jones, 1971), suggesting that animal intake would be limited.

Pensacola bahiagrass was first introduced into Florida in 1935 (Hoveland, 1968) and presently is grown throughout the state for pasture, forage and turf (Jones, 1971). It is the most important grass in terms of hectarage in the state of Florida (Ward and Watson, 1973).

Hemarthria altissima (Poir) stapf and Hubbard (Floralta limpograss) is a perennial tropical grass with short rhizomes and long spreading, decumbent branched stem bases rooting at the nodes. The upper parts of the stems ascend up to 150 cm in height but are usually 30 to 80 cm high. Leaves are up to 20 cm long and 6 mm wide. The inflorescence consists of several racemes appearing singly or in groups of two or four from axillas of the upper leaves (Bogdan, 1977). Limpograss has low seed set under both field and greenhouse conditions (Quesenberry et al., 1978), and has the ability to persist under flooding, drought and freezing temperatures.

Limpograss was first introduced into Florida in 1964 (Oakes, 1965) and it is showing promise in South Florida.

Forage Quality

According to Moore and Mott (1973), forage quality is best defined as output per animal when forage availability is not limiting and when animal potential does not vary between treatments. If the above conditions are met, differences in forage quality and consequently animal output are the result of differences in voluntary intake and nutritive value of the forage being consumed (Mott, 1959).

The main factor controlling animal performance is the quantity of net energy absorbed each day. Three factors control intake of net energy: the quantity of food energy eaten, the proportion of each unit of feed that is digested, and efficiency of utilization of the products of digestion (Minson, 1980). Moore (1980b) pointed out the close relationship between digestible energy intake and animal performance. Thus, another useful definition of forage quality is in terms of voluntary intake of digestible energy. Moreover, indoor studies with cattle fed tropical pastures have shown that the level of animal production is proportional to daily intake of digestible dry matter (Holmes et al., 1966). As voluntary intake of digestible organic matter is closely related to intake of digestible dry matter, both may be used equally to define forage quality.

Raymond (1969) suggested that the quality of a forage should be considered not as a single parameter but as composed of a complex of parameters that determine the net energy intake of ruminants fed on that forage. The importance of this approach was shown by Ingalls et al. (1965), who reported that 70% of the variation in production potential between forages might be accounted for in terms of differences in voluntary intake. So, the value of a forage for animal production is the product of the concentration of nutrients it contains in the forage, its digestibility and the amount of it an animal will eat. The more nutrients an animal eats in excess of its maintenance requirements, the more nutrients available for the deposition of tissues or the secretion of milk, and the greater is the gross efficiency with which the animal converts food into animal products (Osbourn, 1980).

The quality of a pasture is basically a function of the species in the pasture (Butherworth, 1967; Hodges et al., 1974) and the stage of growth (Reid et al., 1973; Abrams et al., 1983), but the quality may be modified by climatic factors during growth (Wilson and Ford, 1973; Mannetje, 1975), soil factors (Chapman and Kretschmer, 1964; Rees et al., 1974), and management factors (Walker and Scott, 1968; Grof and Harding, 1970) which effect pasture regrowth, sward structure and botanical composition.

Nutritive Value

Nutritive value usually refers to the composition of the feed, its digestibility, and the nature of the end products of digestion. A useful nutritional and a simple empirical chemical, division of plant material is into cell contents and cell walls. Although chemically dissimilar, the contents of the cell are nutritionally similar in that they are almost entirely digested by the enzymes of animal's digestive system. Van Soest (1967) showed that cell contents have a constant true digestibility of 98% independent of the composition of the forage. This information suggests that cell contents are rapidly fermented, and their utilization is not affected by cell wall degradation or lignification.

Although the cell wall may be considerably digested by the gastrointestinal microorganisms, it is rarely completely digestible. Thus, fiber is used as a negative index of quality (Van Soest, 1982).

Lignin is not digested either by ruminal microorganisms or by intestinal enzymes. However, its major negative effect is that it inhibits the digestibility of cellulose and hemicellulose (Moore, 1980a), and a decline in digestibility is usually associated with an increase in the proportion of lignified structural tissue. It generally has been accepted that lignin is the main factor limiting digestibility in forages. Abrams et al. (1983) found that lignin was the chemical component most highly related to organic matter digestibility ($r=-.72$) in tropical grasses.

Several authors (French, 1961; Moore and Mott, 1973; Minson, 1980) have mentioned that tropical grasses generally contain more fiber than temperate grasses, thus a lower dry matter digestibility (DMD) might be expected. Minson and McLeod (1970) reviewed data from over 1000 determinations of digestibility of tropical and temperate grasses and reported that tropical grasses averaged about 13 units lower in in vivo DMD. Most samples of temperate grasses had digestibility above 65% but few tropical grasses were in this category. These data are consistent with those reported by Moore and Mott (1973).

The major changes in composition occurring in pasture plants are those that accompany maturation. As the grass plant matures, the proportion of cell walls and their constituent fractions increase and that of the cell content and its fractions decrease (Osbourn, 1980). Consequently, a decline in DMD is expected. Digestibility in tropical grasses declines continuously during growth. Species differ markedly in digestibility at the early vegetative stage of regrowth and in the rate at which digestibility declines with maturity. Tropical grasses generally decrease in DMD at a daily rate of .1 to .2 digestibility units (Minson, 1971a). Limpograss and bahiagrass ranged from 62.6 and 56.0% respectively for total digestible nutrients (TDN), for 4-week old regrowth, to 56.3 and 53.5%, for 8-week old regrowth (Moore et al., 1981).

Forage species which maintain high digestibility for long periods during the growing season are of higher value for animal production than those which may have high digestibility at a young stage of growth but in which digestibility decreases rapidly. Shank et al. (1973) reported a mean decrease of in vitro organic matter digestibility (IVOMD) for limpograss (Bigalta) from 68.4% at 5 weeks to 66.0% for mature plants. Similarly, limpograss (Bigalta) maintained an IVOMD of above 62% in 1976 and 55% in 1977, up to 14 weeks regrowth (Quesenberry and Ocumpaugh, 1980). The decreases in digestibility of limpograss, as the season progressed, were small when compared with the decreases reported for bahiagrass: 55.1 and 46.9% IVOMD (Prates et al., 1974); 65.4 and 57.3% IVDMD (Chapman et al., 1972); 67.9 and 42.9% IVDMD (Utley et al., 1974) between the beginning and the end of grazing season.

Digestibility of a feed also will be lowered if the activity of microorganisms is reduced by a deficiency of an essential nutrient such as nitrogen (Campling et al., 1962) or sulfur (Rees et al., 1974).

Intake

Restricted (quantity and/or quality) nutrient intake is probably the major factor limiting production by grazing animals. Thus, if quantity is not limiting intake, daily dry matter intake (DMI) is the most important single factor controlling quality of tropical pasture (Milford and Minson, 1966). Conrad (1966) outlined two major, theoretical mechanisms controlling voluntary intake: distention and chemostatic mechanisms. With most forages, the distention mechanism is the primary controlling factor, although there may be overlapping with the chemostatic mechanisms when the animal is consuming high quality forages (Moore, 1980b). It is known that a relation exists between the bulk of a food and the intake of that food by ruminants. This relation appears to be associated with the filling effect in the gut, especially in the reticulo-rumen, and hence, is related to such factors as the digestibility and rate of passage of the food through the rumen (Balch and Campling, 1962). Ingalls et al. (1966) found that the intake of fiber and lignin each was negatively related to their respective retention time in the rumen.

The voluntary intake of tropical grasses by ruminants is usually less than that of temperate grasses. This lower intake of tropical grasses applies at all stages of growth and is associated with their higher fiber content, lower DMD percentage, larger quantities of indigestible fiber and the longer time this fiber stays in the reticulo-rumen (Minson, 1980). Moore and Mott (1973) suggested that tropical grasses have consumption rates of 10 to 15 units lower than those of temperate grasses.

The voluntary intake also declines with maturity. Moore et al. (1981) observed that organic matter intake (OMI), as a percent of body weight, declined from 2.46 and 2.26 to 2.22 and 1.74 over an eight-week period for limpograss and bahiagrass, respectively.

Herbage intake will be limited only by the level of fiber in the plant if protein, vitamins and minerals are supplied in sufficient quantities. Tropical grasses generally contain less protein than temperate grasses. Minson (1980) showed that 22% of all observations for tropical grasses fell below 6% crude protein compared with only 6% of all observations with temperate species, a value below which intake is seriously reduced by protein deficiency (Minson and Milford, 1967). For production purposes, a protein level in excess of this is obviously required. Ulyatt (1973) suggested that 12% crude protein is probably sufficient for all purposes.

Measurement of intake of fresh herbage fed indoors could be used for comparison and classification of different herbages and also could be a useful guide to the total amount which would be consumed voluntarily by the animal. However, the relationship between the intake of herbage fed indoors and intake of the same herbage grazed in situ is much more complex, due to additional factors unique to the pasture-animal interface. Grazing offers some degree of selection even under conditions of limited intake. Arnold (1960) suggested that the process of grazing involves both a general eating off in a horizontal plane, together with selection in a vertical plane. Precise estimates of chemical composition of selected herbage can be obtained from esophageal fistulated animals. Reviews on this subject describing surgical, sampling, and analytical procedures have been published (Van Dyne and Torrel, 1964; Harris et al., 1967; Theurer, 1970; McManus, 1981). Numerous studies have shown that selective, grazing cattle ingest pasture which has a botanical and chemical composition different from that on offer to the animal (Hendricksen and Minson, 1980; Milne et al., 1982). Stobbs (1975b) found that the percentage of nitrogen in samples obtained from esophageal fistula was similar to that in upper levels of the sward, which suggests that animals were selecting mainly leaves from the upper levels of the sward.

Other factors which may become particularly important when pastures are grazed are the ease of prehension and herbage availability. Allden (1962) found that the relationship between intake and herbage availability was asymptotic. Moreover, when pasture is sparse, grazing cattle have great difficulties in food prehension. Any deficiency in the amount of herbage present per acre cannot be compensated for by increasing the number of acres of herbage available to the animals (Johnstone-Wallace and Kennedy, 1944). Stobbs (1974a) pointed out a greater difficulty in harvesting more mature swards, and Stobbs (1975a) showed that cattle grazing some tropical swards have difficulty satisfying intake requirements due to low availability or inaccessibility of leaf.

Animal Performance

The true quality of a pasture can be measured only in terms of animal production. Production is achieved only when feed is eaten in excess of that required for maintenance, and relatively small increases in feed quality will lead to large increases in production (Stobbs, 1975a).

Animal production is a function of pasture yield, stocking rate, efficiency of pasture utilization and pasture quality, plus a range of extrinsic factors such as breed and adaptation of the animal, animal health, internal and external parasites and level of husbandry (Whiteman, 1980). In any area being grazed, the output of animal products per unit area is a function of two components, the yield per animal and the number of animals per unit area (stocking rate). Mott (1960) proposed a general model to describe the relationship between animal output and stocking rate. As stocking rate increases, a point is reached where the amount of forage available is equal to the requirement of the animals and, at stocking rates above this point, intake per animal is limited and production per animal declines. However, with tropical pastures there is some difficulty in estimating the amount of pasture which constitutes excess, because greater selectivity of the more nutritious parts is possible with a consequent increase in animal productivity when larger quantities of feed are offered (Stobbs, 1975a).

The higher growth rate of tropical pastures permits higher stocking rates, but individual animal performance, which reflects pasture quality, is often lower. Long term gains of .5 to .6 kg liveweight per day can be obtained in most situations, but gains on the order of 1.0 kg per day usually occur only for short periods (Humphreys, 1978). However, the decline in herbage quality associated with pasture maturity results in much lower liveweight gains. A review of animal performance from grazing experiments in the tropics done by Stobbs (1974c) showed that the mean annual gains were .35 kg per steer per day. Inferior values were reported for Pensacola bahiagrass, .159 kg per steer per day

(Moore et al., 1969) and .250 kg per steer per day (Prates, 1974).

Sward Characteristics

Forage available is the amount of forage present at the beginning of the grazing time plus that which is produced during the time period (Mott, 1980). Herbage intake has been shown to be affected by variation in daily herbage available. An important point emphasized by Greenhalgh et al. (1966) is that an increase in the availability may affect the quantity as well as quality of herbage consumed, since opportunities for selective grazing are increased.

Intake, or production per animal, is asymptotically related to herbage availability (Arnold and Dudzinski, 1966; Chacon and Stobbs, 1976; Stobbs, 1977; Chacon et al., 1978). However, there has been a lack of unanimity on the point beyond which further increases in herbage availability have no affect on intake. Allden and Whittaker (1970) observed increases in consumption of pastures up to availabilities of 3000 kg DM/ha, whereas Cowan and O'Grady (1976) indicated that above 2500 kg DM/ha the amount of pasture available was not limiting milk yield. Moreover, Arnold and Dudzinski (1966) showed that asymptote between intake and herbage available varies from about 1000 to 1800 kg DM/ha for different pasture species. Allden and Whittaker (1970) suggested that much of the lack of agreement in the literature about the relationship between intake and forage availability may be due to the use of DM yield/unit area of land as the measure of pasture availability. Mannetje and Ebersohn (1980) suggested that where pasture contains a seasonally variable amount of dead matter, as in tropical and subtropical climates, the relationship between herbage available and intake applies only to the green fractions of the pasture. Thus, forage available should be expressed as green DM. The relative ineffectiveness of dry pasture as compared with green pasture was well illustrated by Willoughby (1959). He found no correlation between DM herbage availability and liveweight gains, but a positive relationship was recorded with dry weight of green herbage present: an asymptote occurred above 1400 kg dry weight of green herbage/ha. However, Wheeler et al. (1963) observed no correlation between digestible organic matter intake and availability of green herbage over the range of 150 to 2900 kg dry weight/ha.

To simply measure availability of pasture without describing its physical distribution may give no idea of possible feed intake. Plant and sward canopy structure can influence the ease with which herbage is removed from a sward by grazing animals (Stobbs, 1973a, b).

Leaf:Stem Ratio

It generally is recognized that under grazing conditions leaf is the major component of the diet selected. Chacon and Stobbs (1976) showed that when cattle intensively grazed a pasture the uppermost leaves were selected first, followed by leaf-bearing stem. This preference for leaf probably is due to lower energy required to harvest leaf than mature stem, since leaf requires 5 to 10 times less energy than mature stem (Hendricksen and Minson, 1980). Moreover, in tropical pastures, there are large differences in chemical and physical composition of leaf and stem fractions. Stems often are of lower quality than leaves. Stem fraction contains more cell wall contents but less nitrogen than do leaf fractions (Laredo and Minson, 1973; 1975). Stem DMD declines rapidly with age, and mature herbage stem DMD is much lower than that of leaf (Wilson and Minson, 1980). Studies of voluntary intake of separate leaf and stem fractions of tropical grasses have shown that sheep eat more of the leaf than of the stem fraction. This difference is associated with the shorter time that the leaf fraction is retained in the rumen and is not due to differences in DMD (Laredo and Minson, 1973; 1974; Poppi et al., 1980). These authors concluded that the shorter retention time appeared to be caused by the large surface area of the leaf fraction initially available to bacterial degradation.

Several researchers agree that maximum intake occurs when animals can graze dense, leafy swards and that stemmy swards may limit intake even when allowance is high (Stobbs, 1973b; 1975b; Chacon and Stobbs, 1976; Chacon et al., 1978).

Height and Bulk Density

Sward bulk density is defined as dry matter per unit of ground area per unit of canopy height (Ludlow et al., 1982), and sward height is the vertical distance between the base of the tiller and the tip of the longest leaf (Allden and Whittaker, 1970). Bulk density varies greatly between and within pastures due to species characteristics and management (Mannetje and Ebersohn, 1980).

Increasing intake with increasing height usually is apparent in temperate swards. Allden and Whittaker (1970) and Hodgson et al. (1977) showed quite clearly that tiller length of temperate swards was much more closely related to the rate of intake than was yield/ha. Hodgson (1981) also found a progressive increase in intake of temperate swards with increase of the height of the grazed surface and intake appeared to be insensitive to variation in the bulk density of herbage within the grazed horizon.

A decline in intake with increasing height is common in tall-growing, tropical swards. Stobbs (1973a, b) and Barthran (1980) demonstrated several examples of negative relationships between intake and sward height. Despite the high dry matter yield from tropical swards, these swards are loosely packed and sward bulk densities vary between 14 and 200 kg/ha cm compared with a range of 160-440 kg/ha cm recorded from temperate swards (Stobbs, 1973a, b; 1975a, b). Thus, in tropical swards, bulk density apparently has a great influence on intake (Stobbs, 1973b; Chacon and Stobbs, 1976; Hendricksen and Minson, 1980), particularly the leaf bulk density in the top of the swards (Chacon et al., 1978). Laredo and Minson (1973) pointed out that high sward bulk density in tropical pastures may only reflect a high stem yield. These studies suggest that animal production would be increased by management practices which maintain high pasture density and leaf:stem ratio.

Factors Affecting Intake by Grazing Animals

Procedures for estimating intake by grazing animals were described by Corbett (1981) and Le Du and Penning (1982). Many different methods of measuring forage intake are available, but none of them has a high degree of accuracy (Arnold and Dudzinski, 1967; Cordova et al., 1978; Margaret and Holmes, 1981; Meijs et al., 1982; Stockdale and King, 1983a). So, a knowledge of mechanics of the grazing process is important to an understanding of the control of herbage intake in grazing animals. Several researchers agree that studies of grazing behavior help to explain variation in feed intake as well as the quality of feed ingested.

Grazing Behavior

The daily routine of a grazing animal is divided into alternating periods of grazing, ruminating and resting. Grazing may occupy from 6 to 11 hours per day, normally in two major periods, one before dark and one after dawn, with shorter periods during the day and night (Holmes, 1980). This has been observed in both the northern (Hughes and

Reid, 1952; Ruckebusch and Bueno, 1978) and southern hemispheres (Arnold, 1962; Stockdale and King, 1983b). Little attention has been given to the night grazing and some workers have not considered this period of sufficient importance to continue recording grazing time at night (Fernando and Carter, 1970). However, Stobbs (1970) suggested that during the night, cows grazing tropical pastures behave more as individuals rather than as a group, and that high yielding cows can spend a considerable length of time grazing during this period. An analysis by Arnold (1981), of 131 published sets of data on the distribution of grazing time between day and night in all climates, observed that 60% of the variation in the time spent grazing at night was accounted for by differences in the time spent grazing during the day, by day length and by latitude. Stobbs (1970) reported that when a longer grazing time is required to meet the nutritional needs of the cows, this is achieved mainly by lengthening the period of night grazing. This observation disagrees with results found by Stobbs (1977), where the time spent grazing during hours of darkness was considerably lower when cows were offered 15 kg DM/cow/day compared with when they were offered 55 kg DM/cow/day. Similarly, Chacon and Stobbs (1976) pointed out that the proportion of night grazing was lower on swards at later stages of defoliation. The changes in diurnal patterns of grazing and in time spent grazing are the behavioral response of the animal to the physiological effects of climate (Cowan, 1975) and the amount of feed available (Hodgson, 1982). Thus, the duration and, to some extent, the distribution of grazing and ruminating activities may be influenced by sward condition, grazing management, climatic variation and the nutrient requirements of the animal.

It is, therefore, reasonable to expect that grazing behavior reflects variation in feed intake and the quality of herbage eaten. The components of greatest importance are the time spent grazing, the rate of biting during grazing and the size of individual bites of herbage, all of which combine to equal herbage intake (Spedding et al., 1966).

Grazing Time (GT)

When animals are provided with adequate herbage, the amount of dry matter consumed often is closely related to the GT (Fernando and Carter, 1970). Estimates of GT may be derived from continuous monitoring of the activity or by using an interval sampling technique. In interval recording, it is assumed that each record is representative of activity over the time period since the previous record. Gary et al. (1970) found no significant difference between estimates of GT from observations made at intervals of 1, 15, 30 and 45 min, and concluded that observation at 15 min intervals provided a reliable measure of GT. This agrees with the observation interval used successfully by Stockdale and King (1983b). However, recording intervals of 10 min have been used more commonly (Jamieson and Hodgson, 1979a; 1979b; Hodgson and Jamieson, 1981). Continuous records of GT are more accurate, but difficult to carry out unless automatic equipment is available. Several types of automatic equipment have been proposed, such as vibracorders (Allden, 1962), telemetric methods (Nichols, 1966), grazing clock (Jones and Cowper, 1975) and transducer (Penning, 1983).

Vibracorders attached to grazing cattle have been used widely and provide an easy means of measuring two of the more important behavior functions, the time spent grazing and the pattern of grazing (Allden, 1962; Arnold and Dudzinski, 1966; Stobbs, 1970; 1974b; Cowan, 1974; Chacon et al., 1978; Hennessy and Robinson, 1979; Hendricksen and Minson, 1980; Zoby and Holmes, 1983). Jones and Cowper (1975) found that vibracorders overestimated grazing time by 18.3% compared with continuous visual observations. However, Jamieson and Hodgson (1979b) found that mean GT recorded for calves carrying vibracorder was only 7% higher than simultaneous visual record on the same calves. Jones and Cowper (1975) suggested that the longer GT measured with the vibracorder is due to a lack of sensitivity in recording brief pauses in the actual grazing routine. However, if grazing includes short periods of walking while selecting suitable grass for eating, then the vibracorder measures this. Moreover, the presence of observers probably interferes with grazing activity to some extent.

Grazing times usually vary from 7 h on good quality pastures to 12 h during periods of shortage or when pastures are of low quality (Stobbs, 1970). A long GT, indicative of difficulty in satisfying nutritive requirements, has been recorded for cows grazing tropical pastures, even when large quantities of herbage have been available. Grazing time on tropical pastures was 512 min for grasses and 646 min for legumes (Stobbs, 1970). He also observed that cows grazing pure legume swards appeared to have difficulty in harvesting the leafy parts of the plant without consuming much of the fibrous stem. Similarly, Cowan (1975) found a mean GT of 600 min per day for cows grazing a mixed tropical sward, which is considerably above the mean GT reported for cows grazing temperate swards; i.e., 419 min (Chacon et al., 1976) and 400 min (Allden and Whittaker, 1970).

Amount of forage available is another factor influencing GT. Chacon et al. (1978), working with tropical swards, found the longest GT at the highest stocking rates: mean GT were 533, 641 and 684 min at low, medium and high stocking rates, respectively. Similar results were found with temperate swards. Zoby and Holmes (1983) observed an increase of mean GT from 504 to 555 min for low and high stocking rates, respectively. And Allden and Whittaker (1970) observed that as amount of herbage DM present decreased from 3000 to 500 kg/ha, there was a two-fold increase in the time spent grazing. However, Jamieson and Hodgson (1979a) indicated that calves subjected to low herbage allowances under strip-grazed management made little attempt to compensate by increasing GT. This observation was very similar to that reported by Le Du et al. (1979), where cows on rotational grazing did not compensate for restrictions in available herbage by grazing longer. These differences in response may indicate that the animals simply abandoned any attempt to graze closer to the ground but waited for the next allocation of feed. Chacon and Stobbs (1976) found that GT was shortest when rotationally grazed cows were first introduced to new pastures, increased in the middle of the grazing period, but then decreased in the later stages of defoliation despite a reduction in the quantity of herbage on offer. These observations are in agreement with those made by Hendricksen and Minson (1980), with the same management system. Similarly, Stockdale and King (1983b) observed that GT increased as herbage allowance decreased to about 32 kg DM/cow/day, but as herbage allowance decreased further, GT also decreased. Thus, the ability of the animal to make compensating changes in GT may be limited and appears to be dependent in part on the system of grazing management adopted.

Biting Rate (BR)

The total number of grazing bites over a 24 h period may be measured directly or calculated as the product of GT and the mean of BR over the time actually spent grazing. The former approach can be measured using an automatic recording technique. Numerous techniques have been developed to automate the recording of number of bites. Stobbs and Cowper (1972) used a mercury switch in conjunction with a microswitch which was operated by the jaw opening. This recorded separately the number of jaw movements by cattle during grazing, when the head was down, and during rumination together with mastication when the head was in the upright position. Such a method has been used successfully by many researchers (Stobbs, 1973a; 1974a; 1975b; Chacon and Stobbs, 1976; Chacon et al., 1978; Hendricksen and Minson, 1980). Chambers et al. (1981) used a microswitch to monitor jaw movement, an accelerometer to record head movements and a mercury switch to determine if the animal was in the head up or head down position. Estimates of BR (head movements) and jaw movements were derived from measurements on the photographic records of oscilloscope traces. There was close agreement, in both sheep or cattle, between the means of measurements of BR from direct observation and from the bitemeter readings. Moreover, the ratio of jaw movements to head movements was always greater than unity. This suggests that estimates of BR or intake per bite based on records of jaw movements may be misleading. It also suggests that a combination of records of jaw and head movements may give a better indication of the mechanical difficulties of prehending and severing mouthfuls of herbage.

Penning (1983) used transducers, which were operated by a change in voltage proportional to the movement of the jaw, to measure jaw movements. A cassette recorder was used to record the analogue signal produced by the transducers. There was good agreement, in 95% of the comparisons, between visual and transducer estimates of BR.

Welch and Smith (1969) and Law and Sudweeks (1975) measured jaw movements by placing balloons in the submandibular space. This gave a change in air pressure when the jaw was opened. However, such a method has numerous practical limitations, particularly when used with grazing animals.

Nichols (1966) used electrodes to measure the electrical potential of a sheep's jaw muscles, transmitted these signals by radiotelemetry and recorded them on a chart recorder. Grazing, loafing and ruminating periods were clearly differentiated.

Some of these techniques require extremely careful placement and adjustment of the apparatus on the animal, and often lead to loss of data due to failure of the apparatus.

Rate of biting could be estimated over short periods of time by direct observation, using manual recording systems, and the need then is to determine the criteria under which measurements will be made. Two basic procedures have been used. One approach is to record the total number of bites which occur in a fixed time interval. Such a method was used by Allden and Whittaker (1970) and Le Du et al.

(1979). Another approach is to record the time taken to complete a specified number of bites. The following technique was described by Jamieson and Hodgson (1979a). A stop-watch was used to measure the time taken for the animals to make 20 bites and from these records BR was calculated. A record was discarded if an animal raised its head from the sward before it had completed 20 bites. This method was used by Jamieson and Hodgson (1979b), Hodgson and Jamieson (1981), Milne et al. (1982), and Zoby and Holmes (1983). The 20-bite technique provided a measurement of potential BR in relation to the sward in question and was on the average, 16% higher than estimates derived from the 2-min-period observation (Jamieson and Hodgson, 1979a). Manual BR recording techniques concentrate attention on the main grazing periods, so estimates of mean BR over a 24 h period may be biased. This problem could be overcome only by the use of automatic equipment. However, visual observations make it possible to differentiate between manipulative and biting actions, a distinction which is difficult to make with conventional jaw movement recorders.

Biting rate may give a valuable guide to the relative ease with which pastures can be harvested by grazing animals. Moreover, BR provides a more precise measure of feeding behavior than GT (Stobbs, 1974a). Stobbs and Cowper (1972) showed that there was considerable variation in the total number of jaw movements with head down (JMHD) when cows grazed swards of different structure and composition.

Tropical pasture swards are highly heterogeneous and usually have a low bulk density of leaf in the uppermost layers of the sward (Stobbs, 1975b). Stobbs (1974a) found that the daily total JMHD from all periods was higher when cows grazed setaria swards, averaging 24800, compared with a mean of 14830 on barley swards.

Tiller height is also an important factor influencing BR for both temperate and tropical swards. Allden and Whittaker (1970) showed that BR increased progressively as tiller length decreased from 36.7 to 5 cm and then fell sharply as tiller length was further reduced to 3 cm. Similar observations were recorded by Arnold and Dudzinski (1969), Chacon and Stobbs (1976), and Chacon et al. (1978). In contrast, the BR by sheep grazing perennial ryegrass-white clover swards declined significantly from 64 bites/min at the first week of regrowth to 47 bites/min at the third week of regrowth (Milne et al., 1982). This decreased BR could be related to attempts by the sheep to select white clover from within the grazed horizon of the tallest swards, since sheep almost always ingested a diet containing a higher proportion of white clover than existed in the sward as a whole.

Zoby and Holmes (1983) reported that total daily bites for a temperate sward ranged from 26000 for cows on a low stocking rate (6 animals/ha) to 43000 for cows on a high stocking rate (12 animals/ha). This showed that herbage allowance may be another important factor influencing BR.

Bite Size (BS)

Estimates of intake per bite are obtained by dividing intake by the number of grazing bites recorded over appropriate time intervals. This procedure to estimate bite size is susceptible, however, to the cumulative error of estimation of variables used in the calculation. Two basic procedures have been used to estimate short-term intake per bite. Allden and Whittaker (1970) used animals harnessed for fecal and urinary collection and measured their gain in weight over a grazing period of one hour. Corrections also were made for insensible weight losses in other similar fully harnessed animals, which were not allowed access to grazing. This procedure is dependent upon the effective prevention of loss of feces and urine and requires very accurate field weighing facilities.

Another method, which has been more widely used, was proposed by Stobbs (1973a). He measured the weight of extrusa collected from esophageal fistulated animals, which usually were allowed to graze for 20 to 30 min. To ensure quantitative recovery of the herbage ingested, he proposed the use of large fistulas (6-8 cm diameter) which allow a free flow of feed into the collecting bag, and a cylindrical foam rubber plug (10 cm diameter and 10 cm long) placed in the lower esophagus to direct ingested feed into the collecting bag. The amount of material collected divided by the number of bites during the sampling period allows average BS to be calculated.

To estimate long term intake per bite, Le Du et al. (1979) and Hodgson and Jamieson (1981) divided daily herbage intake by total bites. Intake was calculated from estimates of fecal output and digestibility of herbage consumed. Jamieson and Hodgson (1979b) used both methods, Le Du's and Stobbs', to estimate BS. They found that the mean value of measured BS in calves was 24% higher than the mean calculated BS. In each case, records were made of the time the animals actually spent grazing and the number of bites taken over this period.

Generally, BS shows the greatest variation across treatments and the greatest residual variation (Hodgson, 1982), when compared with other eating behavior measurements. Thus, the accuracy of estimated intake, using eating behavior methods, will depend largely on the accuracy of measuring BS. The variation in BS usually is substantially greater than variation in either BR or GT (Stobbs, 1973a; Hodgson, 1981). Correlations between estimated intake and eating behavior measurements indicated that the major factor influencing estimated intake was the BS ingested (Chacon and Stobbs, 1976). So, this parameter usually exerts a dominant influence upon daily herbage intake and, in most circumstances, compensating changes in BR and GT are inadequate to offset changes in intake per bite.

Bite size prehended by grazing cattle varies with pasture species. Stobbs (1974b) showed that mean BS varied between .05 and .50 g of OM per bite on tropical pastures and .31 and .71 g of OM per bite on temperate species.

Canopy structure of the pasture is likely an important factor influencing ease of prehension of herbage. Positive correlations between leaf bulk density or leaf:stem ratio and BS were observed in several experiments with tropical swards (Stobbs, 1973a; 1975b; Chacon and Stobbs, 1976; Chacon et al., 1978). Hendricksen and Minson (1980) pointed out a close, positive relationship between leaf:stem ratio and BS for LabLab purpureus, but only a poor correlation was observed between leaf bulk density and BS. Hodgson (1981) reported that BS of calves and lambs grazing ryegrass swards was related positively to sward height and to total herbage in the grazed horizon. Similar observations were made by Hendricksen and Minson (1980) for LabLab purpureus, and Chacon et al. (1978) for Digitaria decumbens and Setaria anceps. However, the results of Stobbs (1973a, b), with tropical swards, demonstrated a negative relationship between intake per bite and sward height in comparisons within and between swards. Stobbs (1975b) suggested that this response may have been associated with the relatively tall swards involved, which had low herbage densities in the upper horizons.

Pasture yields may be increased by applying nitrogen fertilizer, which usually is accompanied by an increase in bulk density of the sward (Stobbs, 1973a). He observed that BS on a nitrogen fertilized setaria sward averaged .39 g of

OM per bite, whereas BS on an adjacent sparse, unfertilized sward averaged .13 g of OM per bite. Similar results for the same species were reported by Stobbs (1975b). He reported that BS increased linearly with increasing applications of nitrogen, averaging .29, .33 and .37 g of OM per bite, respectively, on 0, 50 and 100 kg/ha treatments. Swards which allowed the largest bites to be prehended had the highest leaf yields and bulk densities.

Herbage allowance is another factor which may influence BS. Chacon et al. (1978) reported that the BS harvested by cows continuously grazing setaria swards was higher under low (.165 g OM/bite) than medium (.082 g OM/bite) and heavy defoliation (.079 g OM/bite). Similarly, Zoby and Holmes (1983) reported that BS for ryegrass swards was significantly higher on low stocking rate (.290 g OM/bite) than on high stocking rate (.205 g OM/bite). However, Le Du et al. (1979) reported that BS was not depressed for strip-grazed cows at low herbage allowance. This is inconsistent with results reported by Jamieson and Hodgson (1979a) for the same management system. They suggested that measurements of BS were successful, but the simple mean of measurements made at the beginning and towards the end of grazing on a strip of herbage may overestimate the mean with declining allowance.

Bite size is influenced also by stage of maturity of both temperate and tropical pastures. Stobbs (1973b) found that BS fell from .33 to .15 g of OM per bite with advancing maturity of tropical pasture. Similarly, Jamieson and Hodgson (1979b) observed a mean BS of 1.66 and .47 mg OM/kg liveweight for the first and sixth weeks, respectively, for temperate pasture. Le Du et al. (1979) also reported that BS for temperate sward declined substantially (from .56 to .30 g of OM per bite) over the grazing season.

Some of the difference in BS among the various studies could be attributed to the different methods used to estimate BS, i.e., in some of them BS was estimated based on jaw movements (Stobbs, 1973a; 1973b; 1974b; 1975b; Chacon et al., 1978), while in others, BS was estimated based on real bites (Jamieson and Hodgson, 1979b; Le Du et al., 1979; Zoby and Holmes, 1983). Since the total number of jaw movements is almost always greater than the total number of real bites, the former procedure could underestimate BS.

Stobbs (1973b) concluded that there was an optimum stage of growth for each pasture species which allowed the grazing animal to prehend the largest bites of herbage. Insufficiency and inaccessibility of herbage restrict intake at earlier and later stage of regrowth.

Intake and Eating Behavior

The daily consumption of herbage by grazing animals is related to the time spent grazing, the number of bites per unit of time, and the average size of each bite. Thus, Intake = GT X BR X BS (Spedding et al., 1966). Estimation of herbage intake using the eating behavior of grazing animals has had considerable merit because it has been reasonably precise. Sampling variability was similar for both cutting and eating behavior techniques. On an individual plot basis, the coefficients of variation were 11.2 and 10.1%, respectively, for cutting and eating behavior techniques (Chacon et al., 1976). However, Hodgson (1982) suggested that it probably is prudent to think of measurements of eating behavior as a means for explaining observed effects of herbage intake rather than as a means of estimating intake itself.

Fatigue limits the time that an animal can spend grazing to about 720 min/24 h (Stobbs, 1970), and bites during grazing rarely exceed 36000/24 h (Stobbs, 1973a). Stobbs (1973a) concluded that daily intake by adult cattle (400 kg) was below maximum when BS was less than .3 g of OM. The correlation between estimated intake and eating behavior measurement indicates that the major factor influencing estimated intake is the BS ingested. The correlation coefficients between these two factors was .98 and .87 in autumn and spring respectively (Chacon and Stobbs, 1976).

Under conditions where the desired food is difficult to harvest, cows compensate for small size of bite by increasing the time spent grazing (Stobbs, 1970) and the number of bites taken (Stobbs, 1974a). In an attempt to compensate for small BS (135 and 132 mg OM/bite for setaria and pangola swards, respectively), steers increased the time spent grazing up to a mean of 707 min (Chacon et al., 1978). However, according to Allden and Whittaker (1970), Chacon and Stobbs (1976), Hendricksen and Minson (1980) and Jamieson and Hodgson (1979b), this compensation was effective only in the early stage of defoliation. In pastures in an advanced stage of defoliaton, the point was reached where GT and BR declined together with a decreasing BS. This resulted in markedly lower herbage intake.

Previous work with bahiagrass and limpograss has shown that limpograss is superior to bahiagrass when harvested and fed to cattle (Moore et al., 1981). However, when limpograss has been grazed by cattle, the rate of liveweight gain has been disappointingly low (Quenseberry et al., 1984). This low gain may have been caused by the animals having difficulty in harvesting sufficient herbage. Measurements of eating behavior could provide a way of explaining the causes of low herbage intake by cattle grazing limpograss.

CHAPTER 3
VARIATION IN SWARD CHARACTERISTICS AND NUTRITIVE VALUE BETWEEN FLORALTA LIMPOGRASS AND PENSACOLA BAHIAGRASS

Introduction

Tropical pasture swards vary considerably in yield, bulk density, plant height (Hutton, 1970) and nutritive value (Moore et al., 1981) depending upon species and stage of maturity. Stobbs (1973a; 1973b; 1975b) has shown that despite the high dry matter yields from tropical pasture swards they are loosely packed compared with temperate swards. When pasture is sparse, grazing cattle experience great difficulty in food prehension (Willoughby, 1959; Arnold, 1964; Hendricksen and Minson, 1980).

Besides several plant and animal factors which control intake when pastures are grazed, ease of prehension may become a particularly important factor (Allden and Whittaker, 1970). Thus, low intake of digestible energy under grazing may be caused by animals having difficulty in harvesting sufficient herbage.

It is generally recognized that under grazing conditions leaf is the major component of the diet selected. Because uppermost leaves are eaten first, followed by leaf bearing stem (Chacon and Stobbs, 1976), variation in canopy structure and nutritive value from the top to the bottom of sward could influence the intake of digestible energy and animal performance. Therefore, to simply measure yield without describing its physical distribution may give no idea of possible feed intake.

No data are available on leaf, stem and nutrient distribution of Floralta limpograss and Pensacola bahiagrass swards. Thus, an experiment was conducted under continuous grazing management, to study changes in sward character of these two dissimilar tropical grasses.

Material and Methods

The experiment was carried out at Beef Research Unit, Gainesville, Florida (30 lat. N and 82.5 long. W) from June 21 to October 28, 1982. The predominant soil of the area is spodosol, classified as pamona series (sandy, silicious, hyperthermic, ultic, haplaquods; USDA, 1982). This series has acid horizons developed in thick beds of sandy and loamy marine sediments. In general, soils of the Beef Research Unit vary from moderately well drained to very poorly drained and are of relatively low fertility. During the rainy season the water table rises to within 50 cm of the soil surface (Koger et al., 1961). Temperature and rainfall data are given for the year 1982 in table 1, as well as the mean rainfall from 1941 to 1970.

Pastures and Grazing Management

There were three replicates of two tropical grass species, Hemarthria altissima (Floralta limpograss) and Paspalum notatum (Pensacola bahiagrass). Both species were planted in 1980, and previously had been grazed by steers.

Table 1. Climatological data at the Beef Research Unit and normal rainfall for Gainesville, Florida.

	1982			Normal Rainfall
	Temperature		Rainfall	
	MAX	MIN		
	C		mm	mm
JAN.	19.2	2.9	163.5	72.1
FEB.	24.5	10.1	72.6	94.0
MAR.	24.9	10.1	127.5	108.2
APR.	26.0	11.8	154.4	76.7
MAY	29.7	11.2	52.6	89.9
JUN.	31.5	17.3	149.1	173.0
JUL.	32.1	17.5	100.1	204.0
AUG.	32.2	16.9	75.7	209.6
SEP.	29.9	15.1	158.7	144.0
OCT.	27.5	13.0	39.4	93.5
NOV.	25.7	9.9	22.9	48.8
DEC.	22.6	8.8	33.8	74.4

Fertilizer was applied uniformly across all pastures in May at rates of 50, 30 and 60 kg/ha of N, P_2O_5 and K_2O. Nitrogen fertilizer also was applied in February and in August, each application at a rate of 65 kg/ha.

Each replicate constituted a paddock of 1 ha which was grazed as one unit. Each paddock was grazed by four Brahman-English crossbred (Angus, Hereford) tester steers that were approximately 15 mo of age and had an average initial weight of 267 kg. Testers were assigned randomly to paddocks at the beginning of the grazing season and they stayed on that paddock for the duration of the season. Additional animals were added or removed to all paddocks as determined by forage availability during the experimental period to ensure equal grazing pressure imposed on each treatment. A mineral mixture and water were on offer at all times.

Collection Periods

The experiment consisted of five 28-day periods. In each 28-day period, measurements were made during each of the first three weeks. During each measurement week sequence, one replicate paddock of each pasture, Pensacola bahiagrass and Floralta limpograss, was sampled. As a result, during each 28-day period all six paddocks were sampled once, for a total of 15 observation weeks.

Sward

Six to nine .5 m^2 areas were selected at random within each paddock, and herbage was harvested in 10 cm deep vertical strata. An adjustable frame was used to cut herbage at the required height. The number and height of sampling sites were chosen to cover the range of heights within a given paddock.

Horizontal strata from each site which had the same number of layers were bulked, thoroughly mixed, and subsampled twice. One of the subsamples (400 g) was oven dried (60 C), weighed, ground and saved for subsequent chemical analyses and in vitro organic matter digestion. The other subsample (50 g) was separated into leaf blade, leaf sheath, stem, dead matter, weed and seed fractions and each fraction was dried (60 C). The proportions of each separated component were expressed as a percentage of the total dry weight. Sward bulk density of organic matter, leaf blade, leaf sheath, stem and dead matter was calculated for each layer in terms of kg/ha cm. Total organic matter, leaf blade, leaf sheath, stem and dead matter on offer (kg/ha) were estimated by summing layers in the same spot. Total organic matter bulk density and total leaf blade bulk density were obtained by dividing total organic matter and total leaf blade on offer by the mean sward height.

Laboratory Analyses

All samples were oven dried at 60 C. After drying, they were equilibrated to air moisture and ground to pass a 1 mm screen. All samples were analyzed for dry matter (DM) and organic matter (OM) by analytical procedures described by AOAC (1975). In vitro organic matter digestibility (IVOMD) was determined by a modification of the Tilley and Terry procedure (Moore and Mott, 1974), and crude protein (CP) determinations were made using a Technicon Autoanalyzer according to procedures of Hambleton (1977). Only 25% of the samples, which represented a range of all samples, was analyzed for ash free neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin according to Goering and Van Soest (1970). Lignin, NDF and ADF for other samples were estimated by near-infrared reflectance spectroscopy according to Norris et al. (1976). Samples in which cell wall constituents were analyzed by Goering and Van Soest (1970) were used for calibration of the instrument.

Statistical Analyses

Data were analyzed by least squares analysis of variance utilizing the General Linear Model (GLM) procedure available in the Statistical Analysis System (SAS, 1982).

The model utilized included fixed effects for grass species and layer, the first order interaction involving these two variables, and the interaction between these two and week. Layer was classified from one to six. Each layer represented a sample taken in a 10 cm deep vertical stratum. Week was included as a continuous variable in all analyses, and based on previous analysis, the highest significant (P<.05) order polynomial was selected for each trait. Sites where the samples were nested within grass species were included in the model as a random effect and were utilized to test grass species effect and to adjust this effect for the effect of site.

The analysis was completed by fitting two models. In the first model, site effect was ignored and constants were fitted for each species effect. In the second model, site was taken into account by absorption. This model provided the constant for grass effect.

Homogeneity of each trait analyzed in relation to sward maturity between the two grasses was evaluated through the interaction involving the continuous variable (weeks) and grass. The test for homogeneity of sward maturity was made by determining the difference in reduction in the sum of squares when fitting the two different models. The first model was fitted to the effect of week pooled over grass effect and the second was fitted to individual grass.

For variables representing total forage on offer, the complete model utilized did not include the effect of layer.

Results and Discussions

Sward Characteristics

Floralta limpograss swards were taller (P<.01) and had more OM (P<.01), leaf sheath (P<.01), stem (P<.01) and dead matter (P<.01) on offer, but lower leaf blade (P<.01) on offer than were Pensacola bahiagrass swards (Table 2). There were species by week interactions (P<.01) for stem, leaf sheath and dead matter. Individual equations for these

Table 2. Least squares means, standard errors (SE) and probabilities (P) for organic matter (OM), leaf blade (LB), leaf sheath (LS), stem (ST), dead matter (DM) on offer, organic matter bulk density (OMBD) and leaf blade bulk density (LBBD) in the whole swards; and height.

	Floralta limpograss	Pensacola bahiagrass	SE	P
OM (Kg/ha)	12200	4820	390	.01
LB (Kg/ha)	714	1470	68	.01
ST (Kg/ha)	7344	292	272	.01
LS (Kg/ha)	490	460	30	.01
DM (Kg/ha)	3552	2256	148	.01
OMBD (Kg/ha cm)	376	215	12	.01
LBBD (Kg/ha cm)	25	68	2	.01
Height (cm)	33	23	3	.01

parameters will be presented in the following discussion and in figures.

There is some evidence from Stobbs (1973b; 1975b) and Chacon et al. (1976; 1978) that animals graze herbage from uppermost layers of the canopy. Chacon et al. (1978) suggested that greater consideration of structure and nutrient content in the sward upper layers should be required rather than considering characteristics of the whole sward.

When just the two top layers of each sward were considered, Pensacola bahiagrass had a higher leaf blade bulk density ($P<.01$), but similar dead matter bulk density ($P<.63$) and lower organic matter ($P<.01$), leaf sheath ($P<.01$) and stem ($P<.01$) bulk densities than did Floralta limpograss (table 3).

Organic matter

Organic matter on offer for both species accumulated at decreasing rate throughout the grazing season. There were no species by week interactions ($P>.05$); thus there was no significant difference in OM accumulated over time between species. The general relationship between OM accumulation and time for data from all observations pooled over species was $y = 3560 + 1414w - 73.8w^2$ ($R^2=.23$), where y = OM on offer and w = week in grazing season.

Floralta limpograss had a higher organic matter bulk density (OMBD) in the whole sward than did Pensacola bahiagrass, the average kg of OM/ha cm was 376 and 215 for

Table 3. Least squares means, standard errors (SE) and probabilities (P) for organic matter bulk density (OMBD), leaf blade bulk density (LBBD), leaf sheath bulk density (LSBD), stem bulk density (SBD), dead matter bulk density (DMBD) in the top 20 cm of swards.

	Floralta limpograss	Pensacola bahiagrass	SE	P
OMBD (Kg/ha cm)	267.8	164.9	14.0	.01
LBBD (Kg/ha cm)	22.4	52.9	2.4	.01
LSBD (Kg/ha cm)	14.3	13.6	1.1	.01
SBD (Kg/ha cm)	143.2	7.4	7.2	.01
DMBD (Kg/ha cm)	82.4	77.4	2.7	.63

Floralta limpograss and Pensacola bahiagrass, respectively (table 2). And there was an increase at decreased rate ($P<.01$) over grazing season for both species (figure 1).

According to Stobbs (1973b; 1975b), tropical grass swards are loosely packed compared with temperate grass swards, ranging from 14 to 200 and 160 to 410 kg OM/ha cm, respectively. The organic matter bulk density recorded in this study for Pensacola bahiagrass swards is in agreement with the low sward bulk densities reported for tropical swards; however, the TOMBD recorded for Floralta limpograss was comparable to those reported for temperate swards.

When OMBD was estimated in 10 cm stratified layers, interactions involving species, layer and week ($P<.01$) were observed. Thus, there was a large seasonal variation in the distribution of OMBD among layers within and between species (figure 2). However, the trend over grazing season for both species was a decrease in OMBD from basal to top layers. Similarly, lower bulk densities of top and medium strata compared to those at the base of tropical swards have been observed (Stobbs, 1973b; Chacon and Stobbs, 1976; Chacon et al., 1978).

The OMBD in the top 20 cm of sward increased ($P<.01$) throughout grazing season for both species (figure 1). Besides changes in growth pattern of the grasses due to season, such an increase also could be a consequence of removal of less dense layers from the top of the swards by grazing steers.

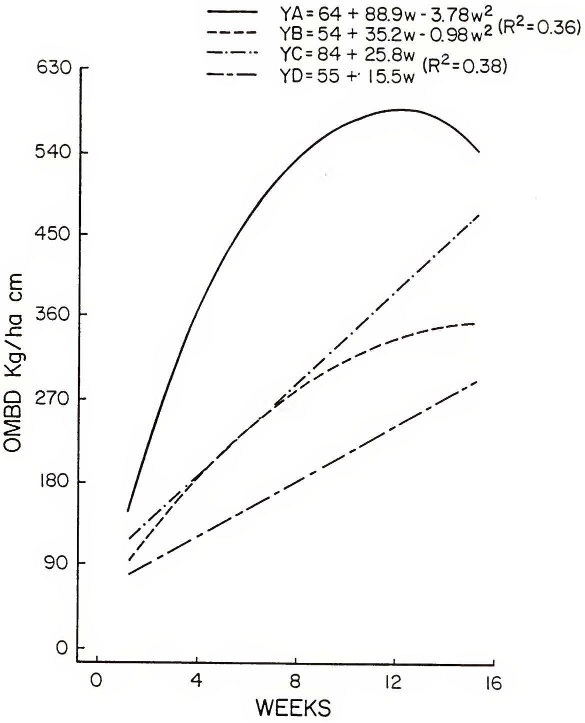

Figure 1. Organic matter bulk density (OMBD), over measurement weeks, for Floralta limpograss whole sward (A), Pensacola bahiagrass whole sward (B), Floralta limpograss top 20 cm sward (C) and Pensacola bahiagrass top 20 cm sward (D).

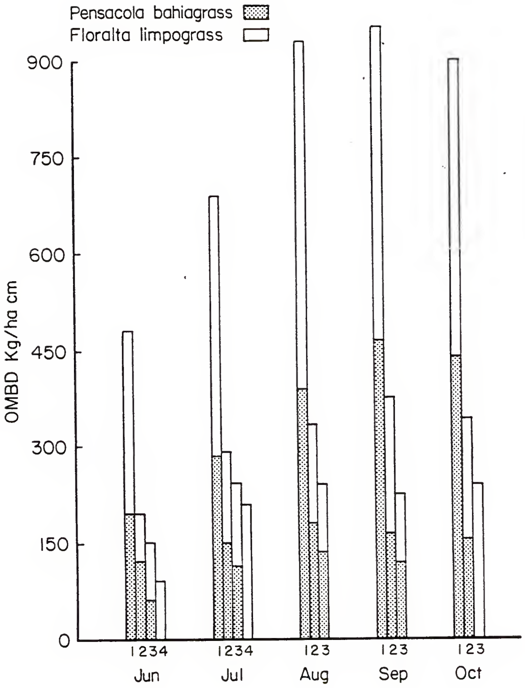

Figure 2. Organic matter bulk density (OMBD) of Floralta limpograss and Pensacola bahiagrass swards in vertical layers from 1, ground to 10 cm; 2, 10 to 20 cm; 3, 20 to 30 cm; and 4, 30 to 40 cm.

Leaf blade

Despite a decrease throughout the grazing season in the percentage of leaf blade (LB) from means of 42 and 23% to means of 25 and 6% for Pensacola bahiagrass and Floralta limpograss respectively, the amount of LB on offer in the whole sward was unaffected ($P<.12$) throughout the grazing season. However, leaf blade bulk density (LBBD) in the sward as a whole increased at decreased rate over the grazing season in Pensacola bahiagrass. But in Floralta limpograss LBBD in the whole sward decreased slightly to week 7, and thereafter, slightly increased (figure 3). Floralta limpograss had a lower ($P<.01$) LBBD in the whole sward than did Pensacola bahiagrass, averaged 25 and 68 kg/ha cm, respectively.

Despite a higher OMBD observed for Floralta limpograss, LBBD was much lower than the values reported for tropical grass swards, which ranged from 55 to 85 kg/ha cm (Chacon and Stobbs, 1976; Chacon et al., 1978; Ludlow et al., 1982). The LBBD observed for Pensacola bahiagrass swards was similar to that for tropical grasses. There were species by layer interactions ($P<.01$) for LBBD. A marked difference in the distribution in LBBD among layers within species swards was observed (table 4). However the trend over grazing season was for a decline in LBBD from basal to top layers for both species. Most of the LB on offer was in the lower layers. Such an observation is in agreement with

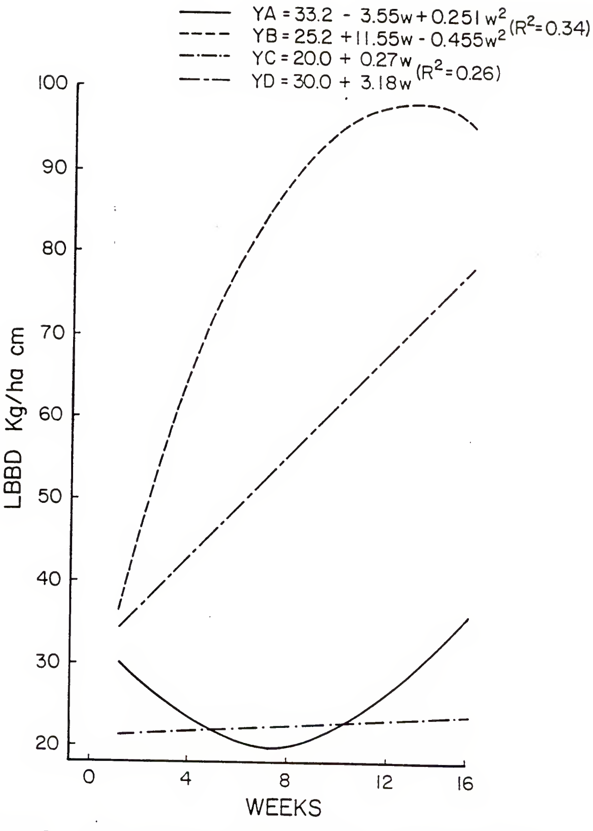

Figure 3. Leaf blade bulk density (LBBD), over measurement weeks, for Floralta limpograss whole sward (A), Pensacola bahiagrass whole sward (B), Floralta limpograss top 20 cm sward (C) and Pensacola bahiagrass top 20 cm sward (D).

Table 4. Vertical distribution of mean leaf blade bulk density (LBBD) and leaf sheath bulk density (LSBD) among layers for Pensacola bahiagrass and Floralta limpograss swards (Kg/ha cm).

Vertical Layers	Pensacola bahiagrass		Floralta limpograss	
	LBBD	LSBD	LBBD	LSBD
0-10 cm	76.8	26.6	23.3	15.6
10-20 cm	72.9	9.0	21.8	13.8
20-30 cm	55.0	2.1	19.4	13.6
30-40 cm	-	-	17.6	11.6

results observed on tropical swards (Stobbs, 1973b; Chacon and Stobbs, 1976; Stobbs and Imrie, 1976; Hendricksen and Minson, 1980).

It generally is known that animals selectively graze the leaf fraction in preference to the stem. Thus, the ability of a pasture species to produce a high density of leaf readily accessible to grazing animals can have a large effect on animal production. Pensacola bahiagrass had a higher ($P<.01$) LBBD in the two top layers than did Floralta limpograss (table 3). Leaf blade bulk density in the top 20 cm of the sward increased markedly in Pensacola bahiagrass throughout the grazing season, but only slightly in Floralta limpograss (figure 3).

Leaf blade bulk density in the two top layers of both species was highly correlated with the quantity of LB on offer ($r=.72$) and with leaf blade:stem ratio ($r=.79$) in the whole sward.

Leaf sheath

There is no evidence that cattle select or avoid the leaf sheath (LS) fraction, with the amount which is ingested being accidental. Observation of the extrusa samples showed that LS was associated almost always with the stem fraction. However, LS was considered separately, since within species it usually has lower nutritive value than LB but higher than stem (Clements et al., 1970; Wilson, 1976).

Leaf sheath on offer decreased linearly over the grazing season for Floralta limpograss swards, but little change was observed for Pensacola bahiagrass (figure 4). There was a species by week interaction ($P<.01$) for LS on offer. Leaf sheath bulk density decreased from the basal to top layers of both species (table 4). However, most of the LS was present in the basal layers in Pensacola bahiagrass swards.

Leaf sheath bulk density (LSBD) in the top 20 cm of Floralta limpograss swards decreased slightly over the grazing period, but increased sharply for Pensacola bahiagrass swards (figure 5). The LS on offer in the top of Pensacola bahiagrass swards was highly correlated with the quantity of stem on offer ($r=.60$) in the whole sward. In the early stages of grazing, four 10 cm thick layers were available. As the season progressed, the paddocks were grazed down and the upper layers which had lesser amounts of LS were removed, leaving late in the season, a shorter sward where the stem fraction was concentrated.

Stem

According to Wilson and Minson (1980), the higher the proportion of stem in the pasture, the lower the proportion of energy transferred to animal production.

The amount of stem on offer in Pensacola bahiagrass swards decreased slightly over the grazing season. Such a decline probably was due to early stem elongation and seed head emergence, since percentage of seed decreased from 13

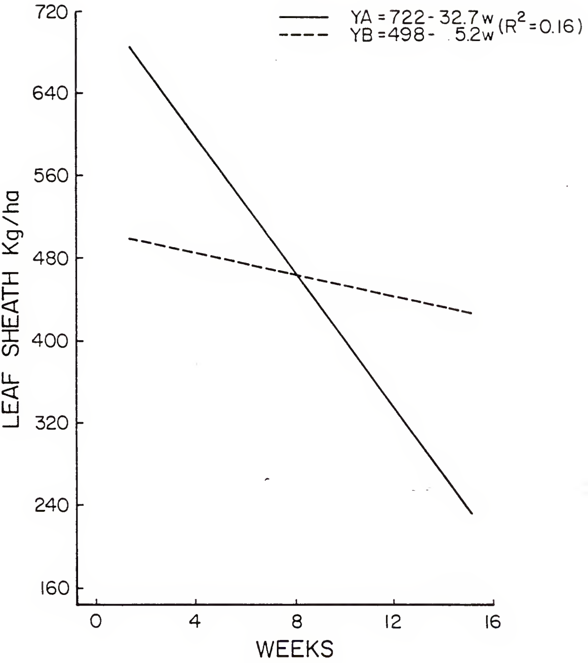

Figure 4. Quantity of leaf sheath on offer, over measurement weeks, for Floralta limpograss (A) and Pensacola bahiagrass (B) swards as whole.

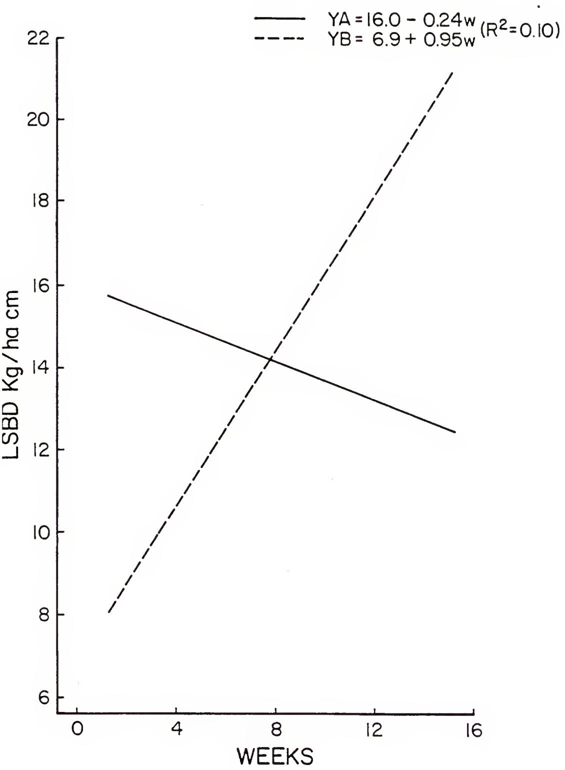

Figure 5. Leaf sheath bulk density (LSBD), over measurement weeks, for Floralta limpograss (A) and Pensacola bahiagrass (B) in the top 20 cm of swards.

at week 2 to 0 at week 10. However, in Floralta limpograss swards, stem on offer increased progressively up to the middle of the season and decreased thereafter (figure 6). Floralta limpograss swards were much stemmier on all occasions (table 2). Since the quantity of stem on offer in Floralta limpograss swards was correlated highly with the green matter on offer (r=.99) in the whole sward, this sharp decline in the amount of green stem on offer for Floralta limpograss during the second half of grazing period appears to be related to an increase over season in percentage of dead matter from 21 to 52%.

There were species by layer by week interactions (P<0.01) for stem bulk density (SBD). Thus, there was a large seasonal variation in the gradient of stem distribution among vertical layers within and between species (figure 7). Stem bulk density decreased from basal to top layers for both species. Such a result is in agreement with that reported by Stobbs and Imrie (1976).

Considering the two top layers, the pattern of SBD variation over season for both species was similar to the pattern of variation for stem on offer in the whole sward (figures 6 and 8). Floralta limpograss consistently had much more stem than did Pensacola bahiagrass swards.

Stem bulk density in the top layers of Floralta limpograss swards was correlated highly with the quantity of OM (r=.86) and stem (r=.93) on offer in the whole sward;

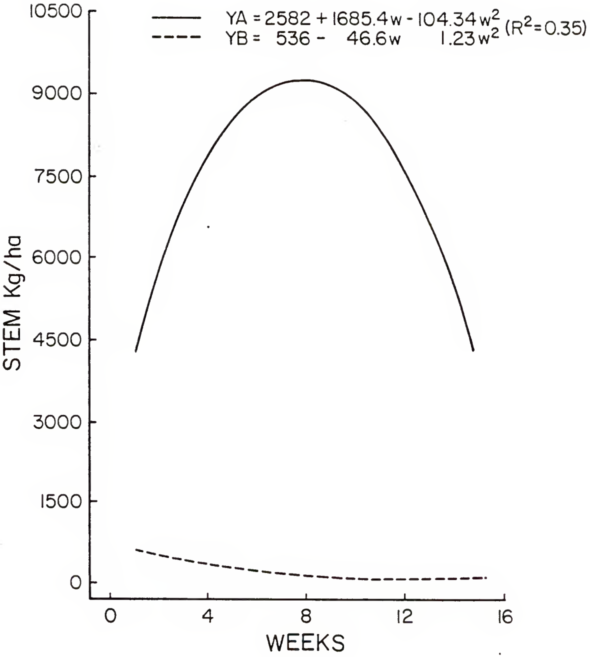

Figure 6. Quantity of stem on offer, over measurement weeks, for Floralta limpograss (A) and Pensacola bahiagrass (B) swards as a whole.

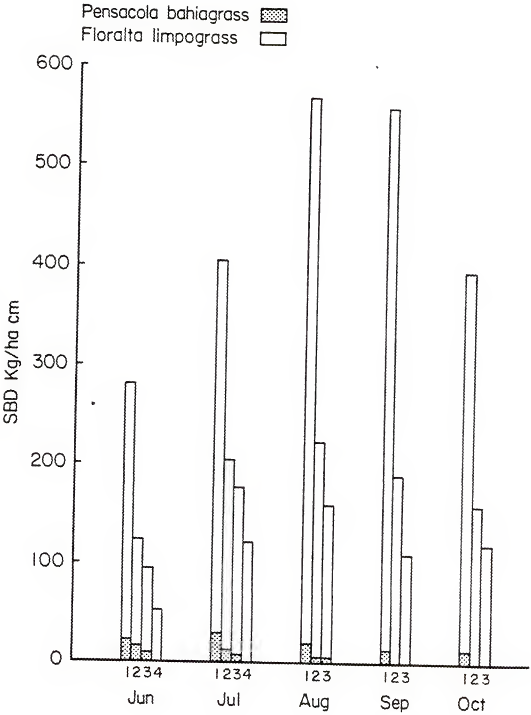

Figure 7. Stem bulk density (SBD) of Floralta limpograss and Pensacola bahiagrass swards in vertical layers from 1, ground to 10 cm; 2, 10 to 20 cm; 3, 20 to 30 cm; 4, 30 to 40 cm.

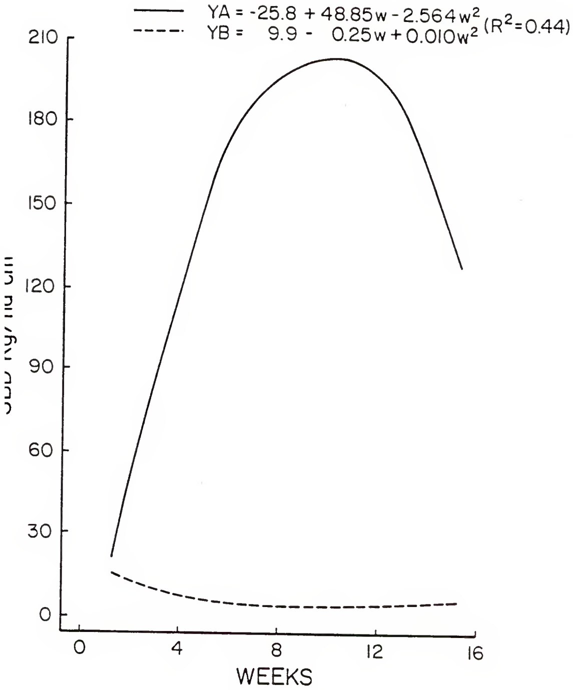

Figure 8. Stem bulk density (SBD), over measurement weeks for Floralta limpograss (A) and Pensacola bahiagrass (B) in the top 20 cm of the swards.

however, for Pensacola bahiagrass it was correlated just with stem (r=.65) on offer in the whole sward.

Where stem yield is high, leaf may be inaccessible to the grazing animal. Thus leaf:stem ratio in the sward also could be an important determinant of intake. Mean leaf blade:stem ratios were .10 and 5.03 in the whole sward, and .16 and 7.16 in the top 20 cm of Floralta limpograss and Pensacola bahiagrass, respectively.

Dead matter

The difference in preference for dead and green pasture by grazing animals is recognized widely. Studies with esophageal fistulated cattle have shown that dead matter (DM) comprises only a small proportion of the animals diet if some green matter is available (Hamilton et al., 1973; Chacon and Stobbs, 1976; Henricksen and Minson, 1980). Thus, the amount of DM on offer likely affects the scope of selection by grazing animals.

The increase in dead matter on offer in the whole sward over the grazing season was almost linear for Floralta limpograss, but quadratic for Pensacola bahiagrass swards (figure 9). Both species had a seasonal build up of DM, as was observed by Willoughby (1959), Yates et al. (1964), Haggar (1970), and Cowan and Stobbs (1976).

There was a species by layer by week interaction (P<.01), since a large seasonal variation in the distribution of dead matter bulk density (DMBD) among layers within and between species was recorded (figure 10). Dead matter

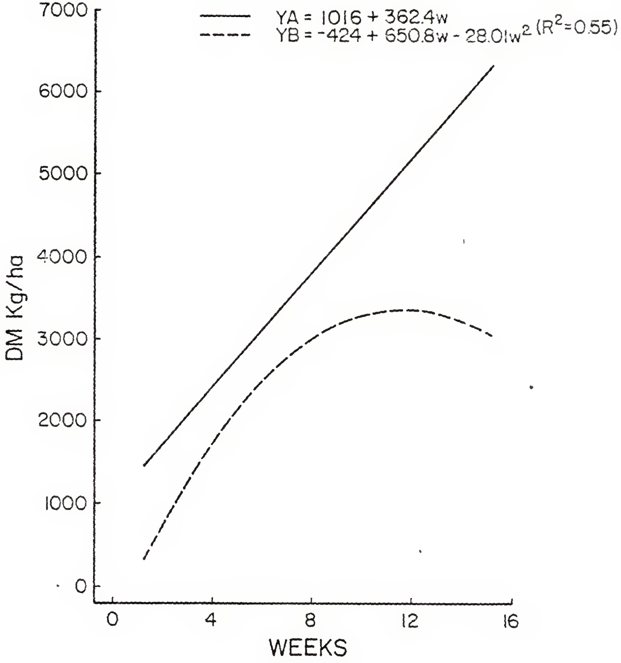

Figure 9. Quantity of dead matter (DM) on offer, over measurement weeks for Floralta limpograss whole sward (A), Pensacola bahiagrass whole sward (B).

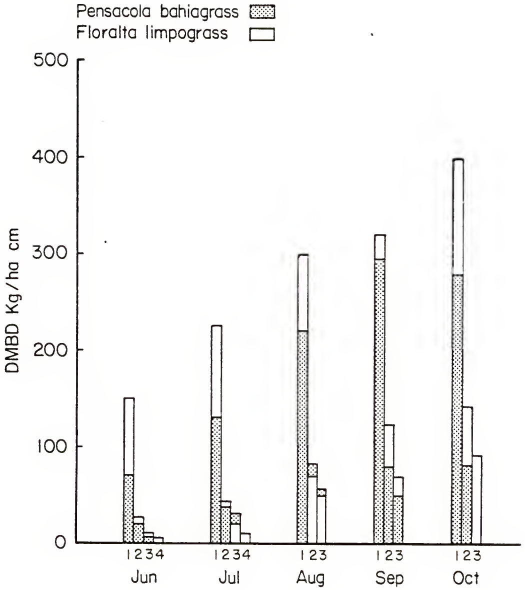

Figure 10. Dead matter bulk density (DMBD) of Floralta limpograss and Pensacola bahiagrass swards in vertical layers from 1, ground to 10 cm; 2, 10 to 20 cm; 3, 20 to 30 cm; 4, 30 to 40 cm.

bulk density decreased from the basal to top layers. However, there was no difference ($P>.63$) between species for dead matter on offer in the two top layers of the sward (table 3).

There was a positive relationship ($P<.01$) between the amount of DM on offer in the top 20 cm of the swards of both of species and the period (week) in which the measurement was made. However there was no significant difference in the regression of DMBD on week between species, and the general relationship from observations pooled over species was $y = -17.4 + 13.68w$ ($R^2=0.49$), where y = DMBD and week of measurement.

Means for ratio of green to dead matter were 2.42 and 1.0 in the whole sward and 2.18 and 0.95 in the top 20 cm of swards, respectively, for Floralta limpograss and Pensacola bahiagrass.

Dead matter bulk density in the top 20 cm of the swards of the two species was correlated with quantity of OM ($r=.75$) and DM ($r=.96$) on offer. Therefore, DMBD in the top 20 cm of swards of Floralta limpograss was highly correlated with SBD ($r=.63$) in the top of the sward, and for Pensacola bahiagrass, DMBD in the top 20 cm of the sward was highly correlated with quantity of LB ($r=.81$) on offer in the whole sward.

Nutritive Value

Crude protein

The mean crude protein (CP) content of Floralta limpograss was lower (P<.01) than that of Pensacola bahiagrass (table 5). Values similar to that of this study were reported for Pensacola bahiagrass by Moore et al. (1969), but Quesenberry et al. (1984) found higher CP values for Floralta limpograss than that observed in this study. There was a species by week interaction (P<.01) for CP content. The relationship of CP content and week by species is presented in figure 11. Declines in CP content as the plant advances in age have been reported for several tropical grasses (Grieveland and Osbourn, 1965; Milford and Haydock, 1965; Moore et al., 1969; Topps, 1969; Minson, 1973). The data reported by these authors support the declines observed in the early and later periods of the grazing season of this study. The increase in CP content in the middle of the grazing season possible can be explained by the fact that 65 kg of N/ha were applied at week 6, since there is some evidence that nitrogen content of tropical grasses may be increased by late application of nitrogen fertilizer (Minson, 1967; Minson, 1973; Prates, 1974; Stobbs, 1975b).

There was a species by layer by week interaction effect (P<.01) on CP content of the grass swards. A large seasonal variation in CP among layers within and between species was observed (figure 12). Crude protein content for both

Table 5. Least squares means, standard errors (SE) and probabilities (P) for crude protein (CP), in vitro organic matter digestibility (IVOMD), neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (LG) contents for Pensacola bahiagrass and Floralta limpograss in the whole swards.

	Pensacola bahiagrass	Floralta limpograss	SE	P
CP (% OM)	7.6	4.3	.1	.01
IVOMD (%)	43.7	53.3	.3	.01
NDF (% OM)	74.9	78.9	.2	.01
ADF (% DM)	43.3	40.0	.2	.01
LG (% DM)	7.5	7.9	.1	.01

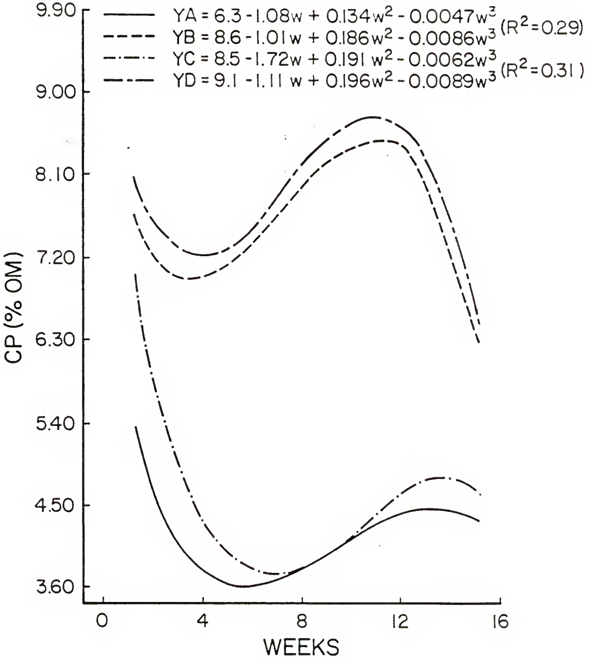

Figure 11. Crude protein (CP) content, over measurement weeks, for Floralta limpograss whole sward (A), Pensacola bahiagrass whole sward (B), Floralta limpograss top 20 cm sward (C) and Pensacola bahiagrass top 20 cm sward (D).

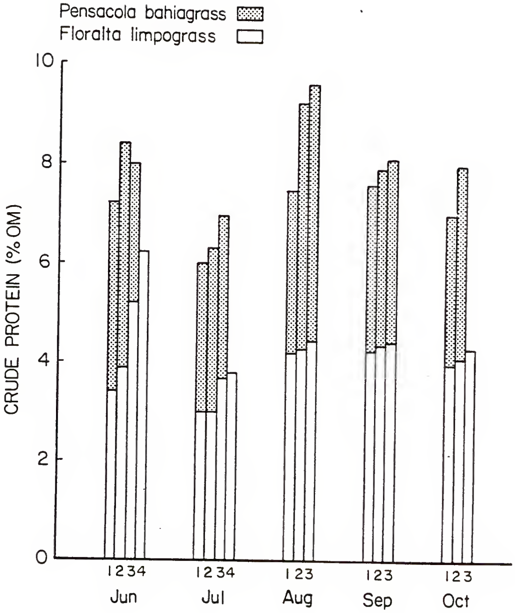

Figure 12. Crude protein content of Floralta limpograss and Pensacola bahiagrass swards in vertical layers from 1, ground to 10 cm; 2, 10 to 20 cm; 3, 20 to 30 cm; 4, 30 to 40 cm.

species decreased from top to basal layers, except for the 20-30 cm stratum of Pensacola bahiagrass at week one, which had less CP than some of the lower layers. Such a decrease could be a consequence of the presence of elongated stems and seed heads in this layer, since the stem fractions has a lower CP content than does the leaf fraction (Stobbs, 1973b; Laredo and Minson, 1973; 1975; Stobbs and Imrie, 1976; Chacon et al., 1978; Ludlow et al., 1982). Content of CP in the top of the swards of both grasses was negatively correlated (P<.01) with SBD in the top of the sward (r=-.83). Several other researchers have reported a decline in CP content from top to basal layers (Stobbs, 1973b; 1975b; Chacon et al., 1978; Ludlow et al., 1982).

Crude protein content in the two top layers of Pensacola bahiagrass sward was higher (P<.01) than that for Floralta limpograss (table 6). Although the CP contents in the top layers of both species were slightly higher than those in the whole swards, the patterns of variations over the grazing season were similar (figure 11).

Crude protein has an important role in the overall quality of tropical grasses. The critical level of CP required in a pasture before intake is reduced by nitrogen deficiency has been estimated at 6% (Minson and Milford, 1967). Considering the CP content just in the top of the swards, that part of the sward that is readily accessible to grazing animals, Pensacola bahiagrass swards presented levels superior to the critical value at all measurement

Table 6. Least squares means, standard errors (SE) and probabilities (P) for crude protein (CP), in vitro organic matter digestibility (IVOMD), neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (LG) contents for Pensacola bahiagrass and Floralta limpograss in the top 20 cm of the swards.

	Pensacola bahiagrass	Floralta limpograss	SE	P
CP (% OM)	7.9	4.7	.2	.01
IVOMD (%)	44.3	54.9	.3	.01
NDF (% OM)	75.2	78.5	.2	.01
ADF (% DM)	43.4	39.1	.2	.01
LG (% DM)	7.4	7.1	.1	.05

periods; however, except for the first week the CP content of Floralta limpograss swards was far lower than the critical value.

Digestibility

Floralta limpograss was more digestible (IVOMD) ($P<.01$) than Pensacola bahiagrass (table 5). This finding is in agreement with results reported by Moore et al. (1981). The relationship between digestibility and maturity was best fitted by a quadratic curve; however, there was no species by week interaction ($P>.05$). Thus there were no differences in the regression of digestibility on week between species. The regression equation from all observations pooled over species was $y = 57.8 - 1.67w + 0.039w^2$ ($R^2=.78$), where y = digestibility and w = week. Although both species had common slopes, they had different intercepts (62.4 and 52.9% IVOMD for Floralta limpograss and Pensacola bahiagrass, respectively).

The rate of decrease in digestibility of the two grasses declined throughout the grazing season. It is generally recognized that the digestibility of herbage declines as the plants mature. The daily rate of decrease in digestibility of tropical herbage is generally about .1 units (Minson, 1971a). However, where young stages of growth have been compared, higher daily rates of decline in digestibility usually have been found (Grieve and Osbourn, 1965; Playne, 1970; Minson, 1971b). These findings are in agreement with the pattern of decline in digestibility found in this study, i.e., a higher decline in the early season.

There was a species by layer interaction (P<.01) on digestibility, with a large difference in digestibility among layers within species. Digestibility increased from basal to top layers in both species, except for the uppermost layers in Pensacola bahiagrass swards, which were less digestible than some of the lower layers (table 7). This lower digestibility in the uppermost layers of Pensacola bahiagrass swards might be a consequence of the presence of elongated stems and seed heads, since Haggar and Ahmed (1971) reported that after ear emergence the in vitro digestibility of stems declined, whereas that of leaves did not change significantly. Moreover stem fraction is less digestible than leaf fraction (De La Torre, 1974; Wilson and Minson, 1980; Ludlow et al., 1982). In vitro digestibility of the top of both swards was highly correlated with amount of LB on offer in the whole sward (r=.80) and with leaf blade:stem ratio (BSR) in the top of swards (r=0.45). Similarly, Stobbs (1973b; 1975b), Chacon et al. (1978), and Ludlow et al. (1982) reported that basal layers were less digestible than upper layers in tropical grass swards.

The top 20 cm of Floralta limpograss was more digestible than the same layer of Pensacola bahiagrass (table 6). There was no species by week interaction (P>.05); thus both species had common slopes but different intercepts (figure 13). Although the intercepts for both

Table 7. Vertical distribution of mean percentage for in vitro organic matter digestibility (IVOMD), neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin (LG) for Pensacola bahiagrass and Floralta limpograss.

Vertical Layers	Pensacola bahiagrass				Floralta limpograss			
	IVOMD	NDF	ADF	LG	IVOMD	NDF	ADF	LG
0-10 cm	41.6	74.0	43.4	8.2	49.2	79.3	42.6	9.8
10-20 cm	48.8	77.0	42.9	6.7	55.2	79.9	38.7	7.3
20-30 cm	47.6	78.5	44.5	7.2	57.3	78.9	37.6	6.3
30-40 cm	-	-	-	-	58.4	78.4	37.4	5.8

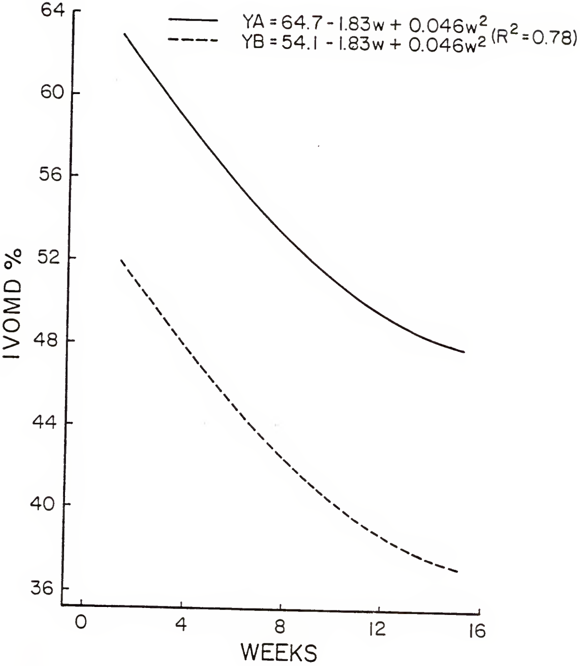

Figure 13. In vitro organic matter digestibility (IVOMD), over measurement weeks, for Floralta limpograss (A) and Pensacola bahiagrass (B) in the top 20 cm of swards.

species were slightly higher than those for in vitro digestibility in the whole sward, the pattern of variation over the season was similar.

Cell wall

Cell wall is rarely completely digestible by gastrointestinal microorganisms. Thus, cell wall is used as a negative index of quality (Van Soest, 1982). Floralta limpograss had higher ($P<0.01$) cell wall, as estimated by neutral detergent fiber (NDF) and lignin, but lower ($P<0.01$) acid detergent fiber (ADF) than Pensacola bahiagrass in both the whole sward and in the top layers (tables 5 and 6).

Species by week interactions affected ($P<.01$) all cell wall constituents. Neutral detergent fiber content of Floralta limpograss increased slightly over the weeks studied, but decreased in Pensacola bahiagrass swards (figure 14). These results disagree with several other studies in which sharp increases in NDF with maturity were observed (Colburn and Evans, 1967; Haggar, 1970). However, Prates et al. (1974) reported a decrease in NDF content of Pensacola bahiagrass late in the season. Such a decline in NDF content over the grazing season might be in part a consequence of the decline in the amount of stem on offer over the season, since NDF content for both species was highly correlated with the amount of stem ($r=.80$) and LB ($r=-.84$) on offer in the whole swards. This result agrees with the observation by De La Torre (1974) that stem has more NDF content than does the leaf fraction.

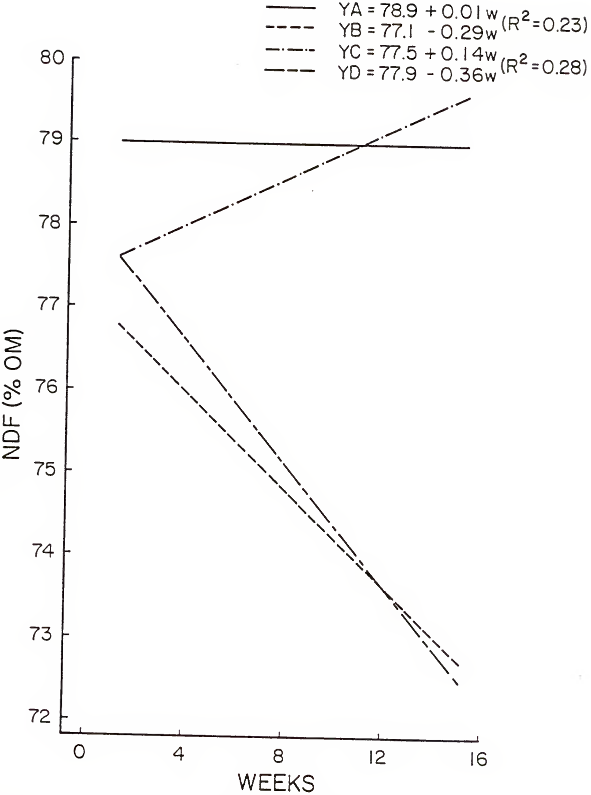

Figure 14. Neutral detergent fiber (NDF) content, over measurement weeks, for Floralta limpograss whole sward (A), Pensacola bahiagrass whole sward (B), Floralta limpograss top 20 cm sward (C), and Pensacola bahiagrass top 20 cm sward (D).

Throughout the season, ADF increased linearly and lignin increased quadratically, for both species (figures 15 and 16). Although Floralta limpograss had a much smaller lignin content than did Pensacola bahiagrass at the early stages of growth, it had a higher increase in lignin content over the season. Similarly, increases in ADF and lignin with maturity have been reported frequently (Waite, 1970; Prates et al., 1974). Lignin and ADF contents for both species were highly negatively correlated with green:dead matter ratio (GDR) ($r=-.70$ and $r=-.75$, respectively).

Species by layer interactions affected ($P<0.01$) all cell wall constituents. There were differences in NDF, ADF and lignin contents among layers within species (table 7). All cell wall constituents decreased from basal to top layers in Floralta limpograss swards; however, in Pensacola bahiagrass swards, NDF increased from basal to top layers, ADF was constant, except for the uppermost layer which had highest ADF, and lignin decreased from basal to top layers, except for the uppermost layer which had higher content than medium layers. These highest NDF, ADF and lignin contents of the uppermost layer in Pensacola bahiagrass swards might be a consequence of the lower BSR in this layer, since cell wall constituents were negatively correlated ($P<.01$) with BSR ($r=-.70$) in the top 20 cm of both species swards. These results confirm the observations of others (De La Torre, 1974; Laredo and Minson, 1973; 1975).

Mean NDF, ADF and lignin contents in the top layers were similar to those in the whole sward, except for lignin

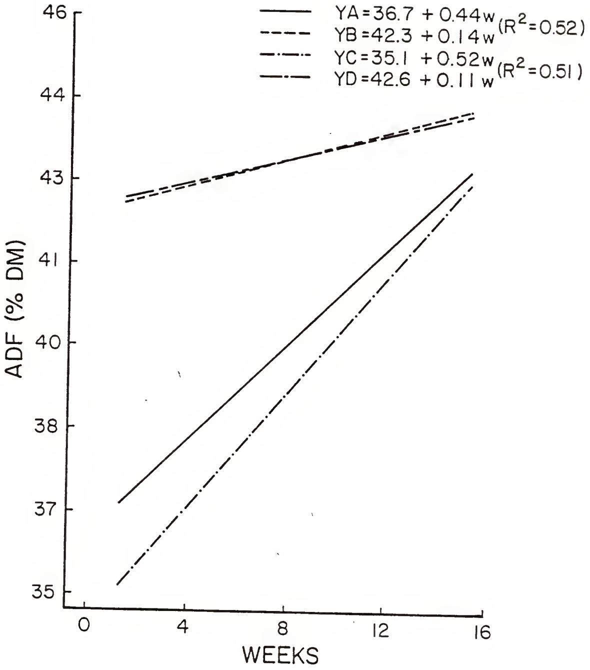

Figure 15. Acid detergent fiber (ADF) content, over measurement weeks, for Floralta limpograss whole sward (A), Pensacola bahiagrass whole sward (B), Floralta limpograss top 20 cm sward (C), and Pensacola bahiagrass top 20 cm sward (D).

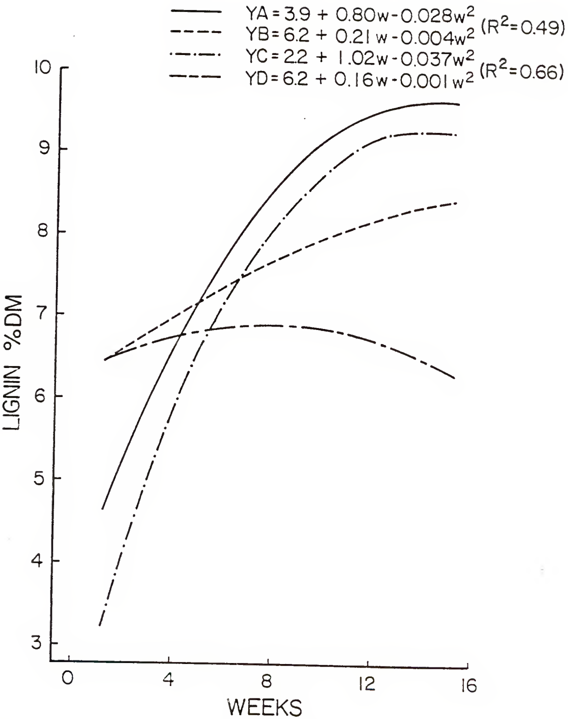

Figure 16. Lignin content, over measurement weeks, for Floralta limpograss whole sward (A), Pensacola bahiagrass whole sward (B), Floralta limpograss top 20 cm sward (C), and Pensacola bahiagrass top 20 cm sward (D).

in the top layers of Floralta limpograss, which was a little lower than that in the whole swards (tables 5 and 6). The pattern of variation over grazing season in all cell wall constituents in the top layers was similar to that in the whole sward.

Summary and Conclusions

A continuous grazing experiment was conducted from June to October 1982, to study changes in sward characteristics of Pensacola bahiagrass (Paspalum notatum) and Floralta limpograss (Hemarthria altissima). There were three replicates of the two species, each replicate constituted a paddock of 1 ha which was grazed as one unit. Besides four tester steers with an initial weight of approximately 267 kg, additional animals were added or removed to all paddocks, as required to ensure equal grazing pressure on each treatment.

The experiment was carried out during five 28-day periods in each of which measurements were made during each of the first three weeks. During each measurement week, one replicate paddock of each grass species was sampled. As a result, during each 28-day period all six paddocks were sampled once each. Six to nine .5 m areas were selected at random within each paddock, and herbage was harvested in 10 cm deep vertical strata.

The response variables obtained in each measurement week consisted of structural characterizations and nutritive value of each grass species. These included quantity of organic matter, leaf blade, leaf sheath, stem matter on offer in the whole swards and sward bulk densities of the above variables in the top 20 cm, total organic matter and leaf blade densities, vertical distribution of organic matter, leaf blade, leaf sheath, stem, dead matter, crude protein, neutral detergent fiber, acid detergent fiber, lignin and in vitro organic matter digestibility among layers.

The results of this study permit the following conclusions.

1) Organic matter on offer for both species accumulated at a decreasing rate over the grazing season; however, the two species were quite different in total forage on offer and in the seasonal variation in the gradient distribution of plant component in the swards.

2) Although Floralta limpograss had a higher total organic matter bulk density during the grazing period, total leaf blade bulk density was much lower in all occasions than Pensacola bahiagrass swards.

3) The general trend over the grazing season in both species was a decrease in the bulk densities of organic matter, leaf blade, leaf sheath, stem and dead matter from basal to top layers.

4) The increase over the season for leaf blade bulk density in the top 20 cm of Pensacola bahiagrass

was much higher than that of Floralta limpograss swards, which was much stemmier on all occasions.

5) The increase in dead matter bulk density in the top 20 cm was similar for both species; however, Floralta limpograss had a higher green:dead matter ratio on all occasions. Pensacola bahiagrass was shorter and the top 20 cm often included layers that were close to the ground, thus had a higher buildup of dead matter.

6) The nutritive value decreased over the grazing season for both species, and the general trend was an increase in crude protein content and in vitro organic matter digestibility and a decline in lignin content from basal to top layers.

CHAPTER 4
ESTIMATION OF HERBAGE INTAKE BY STEERS GRAZING PENSACOLA BAHIAGRASS AND FLORALTA LIMPOGRASS USING EATING BEHAVIOR MEASUREMENTS

Introduction

The main factor which determines the level of animal production from pastures is the amount of digestible nutrients consumed. Ingalls et al. (1965) reported that 70% of the variation in production potential between forages might be accounted for by differences in voluntary intake. Moreover, Milford and Minson (1966) suggested that feed intake provides the best single index of the reaction of a grazing animal to its environment.

However, under grazing conditions, actual intake by grazing animals can not be measured, and estimates of the actual intake must be done by indirect techniques. Several researchers agree that studies of eating behavior help to explain reasons for variation in the intake as well as to estimate the actual quantity of herbage ingested (Allden and Whittaker, 1970; Stobbs, 1974a, b; Chacon et al., 1976; Hendricksen and Minson, 1980).

The daily herbage intake by grazing animals is a product of the time spent grazing, the number of bites per unit of time and the average size of each bite (Spedding et al., 1966). Measurements of components of eating behavior have provided valuable comparisons of different pasture conditions. Long grazing time is indicative of difficulty in satisfying nutritive requirement. Several authors have shown that grazing times varied from 7 h on good quality pastures to 12 h on low quality pastures or when feed is scarce (Stobbs, 1970; Cowan, 1975; Chacon et al., 1978).

Biting rate may give a valuable estimate of the relative ease with which pastures can be harvested by grazing animals. Chacon and Stobbs (1976) suggested that the major factor influencing estimated intake was the bite size ingested. It has been reported that there is considerable variation in the total number of bites and bite size prehended by animals grazing swards of different species (Stobbs, 1974b; Chacon et al., 1976), structure (Stobbs and Cowper, 1972; Stobbs, 1975b), tiller height (Arnold and Dudzinski, 1969; Allden and Whittaker, 1970; Chacon and Stobbs, 1976), herbage allowance (Chacon et al., 1978; Zoby and Holmes, 1983), and botanical composition (Milne et al., 1982).

An experiment was conducted under continuous grazing to study changes over season in the eating behavior components of animals grazing Floralta limpograss and Pensacola bahiagrass, and to relate the components to intake and animal performance. Comparisons were made between eating behavior and the sward characteristics reported in Chapter 3.

Material and Methods

The experimental time consisted of five 28-day periods. In each 28-day period, measurements were made during each of the first three weeks. During each measurement week, one replicate paddock of each pasture of Pensacola bahiagrass (Paspalum notatum) and Floralta limpograss (Hemarthria altissima) was sampled. As a result, during each 28-day period all six paddocks were sampled once, for a total of 15 observation weeks. Experimental details about management and sampling of pasture swards were reported in Chapter 3.

Grazing Behavior, Esophageal Sampling and Estimated Intake

Four mature, crossbred, esophageal fistulated steers were used to sample pastures, to measure eating behavior, and to estimate intake. They were assigned randomly to pairs. Three days before starting the first collection period, each pair was allocated at random to reserve pastures of Pensacola bahiagrass or Floralta limpograss. They were moved to an experimental paddock of the same species during collection. Fistulated steers had access to the experimental paddocks only during 4-day collection periods. After each collection period steers were moved to the alternate reserve paddock of the other grass species, to avoid two consecutive sampling periods on the same pasture species.

Grazing time was recorded with vibracorders[1] (Stobbs, 1970) for two successive days each week. On Day 1 (0800 h) of each week, vibracorders were attached to the esophageal fistulated steers before they were moved to the paddocks and removed on Day 4. Bite size and biting rate determinations were carried out at 0800 and 1400 h twice on Day 4 of each week. These measurements were made on the esophageal fistulated steers during the collection of extrusa samples, following an overnight fast. Collection periods were 20 minutes long. The time was stopped if the steer failed to bite for more than 2 minutes and resumed when grazing began again.

Number of bites was recorded by visual observation, with the aid of a hand counter. Each animal was watched by an observer. Each bite was distinctly audible and easily distinguished from non-biting jaw movements. From these records, number of bites per minute during active grazing was calculated. The morning and afternoon records for each animal were used to calculate the mean biting rate per day.

At the time number of bites was recorded, total number of jaw movements was recorded using an electronic event counter activated by a muzzle switch. A submini-lever switch[1] mounted in Plexiglas was attached to a muzzle band made of a canvas strap, elastic band and Velcro. The band was placed around the muzzle in such a way that when the jaw opened, the lever switch was closed. The electronic event counter[2] was mounted in a plastic box and connected to the muzzle switch in order to record each opening of the jaw. An in-line switch was opened if the animal's head was up; thus, only jaw movements with the head down in grazing position were recorded. Before each observation period the counter was reset to zero. Rate of jaw movement in minutes was calculated as the total counts divided by the observation time. The ratio between rate of actual bites (AB) to rate of total jaw movements (JM) was expressed, in percent, as the bites:jaw movement ratio (BJMR).

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[1] TFN 24/8 Stop and Go Recorder, Argo Instruments, Inc., 980 Brooke Road, Winchester, VA 22601.

Esophageal collection bags were made from vinyl covered canvas, with vinyl gauze bottoms to facilitate drainage of saliva. Each sample was weighed fresh, thoroughly mixed and subsampled twice. One subsample was oven dried (60 C), weighed, ground, and saved for subsequent chemical analyses and in vitro digestibility. Another sample was separated by hand into leaf blade, stem (true stem and sheath), dead matter, and weed fractions. Fractions were dried, weighed, and the proportions expressed as a percentage of the total dry weight. Intake of organic matter per bite was calculated by dividing the total organic matter weight of the extrusa collected by the number of real bites recorded during the time interval of collection.

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[1] Cat. No. 275-016, Radio Shack, Tandy Corp., Fort Worth, TX 76012.

[2] Model PC-4, Non-linear Systems, Inc., Box N, Del Mar, CA 92014.

Recovery Trial

It is essential to ensure complete recovery of herbage ingested, for estimates of bite size and subsequent intake. For this purpose, it has been recommended that a foam rubber plug be placed in the esophagus just below the fistula (Stobbs, 1973a). However, plugs of this kind were unsuccessful in this experiment because they would not stay in place. Thus, a trial to check recovery of ingested herbage was conducted after the afternoon collection of extrusa samples. The steers were moved to an adjacent concrete pen where they were hand fed. Floralta limpograss and Pensacola bahiagrass were cut in the reserve pastures. Each steer was fed 1 kg of Floralta limpograss or Pensacola bahiagrass, cut into 5 to 8 cm lengths, according to the pasture the steer was grazing. The percentage of herbage recovered was obtained by dividing the dry matter weight of esophageal extrusa by the dry matter weight of feed offered minus feed refused. The percentage of recovery estimated for each steer each day was used to adjust the amount of extrusa to the amount expected if all herbage ingested had been extruded into the collection bags. The adjusted amount of extrusa was used to estimate corrected bite size.

Intake and Animal Performance

Daily intake (I) of herbage by each steer was estimated as the product of three variables: time spent grazing (GT), biting rate (BR) during the grazing period and corrected bite size (BS). Thus, I (g of OM/day) = GT (min/day) X BR (bites/min) X BS (g of OM/bite). The total number of grazing bites per day was calculated as the product of GT X BR.

Individual weights of tester steers were taken at 28-day intervals during the grazing season. Experimental details about management of animals were given in Chapter 3.

Laboratory Analyses

All esophageal extrusa samples were oven dried at 60 C. After drying, they were equilibrated to air moisture and ground to pass a 1 mm screen. Esophageal extrusa samples were analyzed for dry matter (DM) and organic matter (OM) by analytical procedures described by AOAC (1975). In vitro organic matter digestibility (IVOMD) was determined by a modification of the Tilley and Terry procedure (Moore and Mott, 1974), and crude protein (CP) was analyzed using a Technicon Autoanalyzer according to procedures of Hambleton (1977). All samples were analyzed for ash free neutral detergent fiber (NDF), and 25% of the total samples, which represented a range of all samples, were analyzed for acid detergent fiber (ADF) and lignin according to Goering and

Van Soest (1970). Lignin and ADF for other samples were estimated by Near-Infrared Reflectance Spectroscopy according to Norris et al. (1976). Samples in which cell wall constituents had been analyzed by Goering and Van Soest (1970) were used for calibration of the instrument.

Statistical Analyses

Data were analyzed by least squares analysis of variance utilizing the General Linear Model (GLM) procedure available in the Statistical Analysis System (SAS, 1982).

The model utilized included fixed effects for grass species, steers and time of collection (morning and afternoon), first order interactions involving these three variables, and interactions between grass and week. Week was included as a continuous variable in all analyses, and based on previous analyses, the highest significant ($P<.05$) order polynomial was selected for each trait.

Homogeneity of variance of each trait analyzed, in relation to sward maturity between the two grasses, was evaluated through the interactions involving the continuous variable (week) and grass species. The test of homogeneity for week was conducted by using the difference in reduction in the sum of squares when fitting two different models. The first model was fitted to the effect of week pooled over grass species, and the second was fitted to individual grass species.

The best multiple regression of sward traits on traits of grazing behavior was selected based on the Maximum R Program available (SAS, 1982).

Results and Discussion

Diet Selectivity

Steers were without feed for 15 h prior to sampling. An effect of fasting on selectivity was not expected, since Chacon and Stobbs (1977) observed similar nitrogen content in diets selected after 2 and 16 h fasting. Similarly, Cohen (1979) reported that the length of a pre-collection fast up to 23 h did not significantly bias estimation of nutritive value of extrusa.

Animals on Floralta limpograss swards selected a diet more digestible ($P<.01$), but similar in NDF ($P<.09$) and in lignin ($P<.25$) and lower in CP ($P<.01$) and in ADF ($P<.01$) than that selected by steers grazing Pensacola bahiagrass swards (table 8). There were species by week interactions ($P<.01$) for IVOMD, CP, ADF, and lignin.

There was a negative linear relationship between IVOMD content of the diet selected by grazing steers and week (figure 17). Extrusa samples from animals grazing Floralta limpograss had higher IVOMD on all occasions; however, IVOMD of Floralta limpograss decreased more rapidly over the grazing season than did that of Pensacola bahiagrass. Floralta limpograss selected by grazing animals was similar in IVOMD to that on offer in the top 20 cm of sward. However, IVOMD of Pensacola bahiagrass selected average 4.5

Table 8. Least squares means, standard errors (SE) and probabilities (P) for in vitro organic matter digestibility (IVOMD), crude protein (CP), neutral detergent fiber (NDF), acid detergent fiber (ADF) and lignin contents of esophageal estrusa of steers grazing Pensacola bahiagrass and Floralta limpograss pastures

	Floralta limpograss	Pensacola bahiagrass	SE	P
IVOMD (%)	53.9	48.4	.4	.01
CP (% OM)	5.8	9.3	.2	.01
NDF (% OM)	79.8	77.7	.9	.09
ADF (% DM)	44.1	47.5	.2	.01
Lignin (% DM)	9.2	9.4	.1	.25

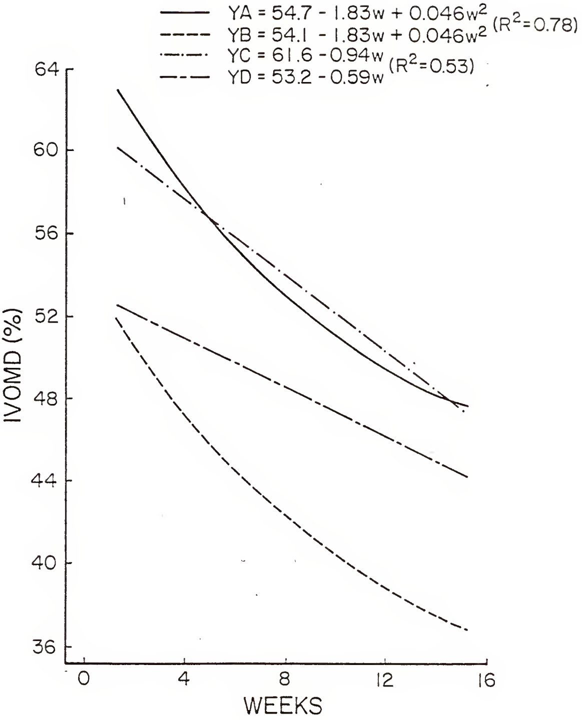

Figure 17. In vitro organic matter digestibility (IVOMD), over measurement weeks for Floralta limpograss for top 20 cm sward (A), Pensacola bahiagrass for top 20 cm sward (B), Floralta limpograss esophageal extrusa sample (C), and Pensacola bahiagrass esophageal extrusa sample (D).

percentage units higher than that on offer in the top 20 cm of sward.

The IVOMD of the diet selected by steers was correlated (P<.01) with IVOMD (r=.90, .74), dead matter (r=-.84, -.61), and leaf blade:stem ratio (r=.54, .52) in the top 20 cm of swards (Floralta limpograss and Pensacola bahiagrass, respectively).

The pattern of variation in CP content of herbage selected over the grazing season followed a similar pattern to the CP content of herbage on offer (figure 18). However, the CP content of herbage selected for both species was higher than that on offer in the top 20 cm of sward. Crude protein content of herbage selected averaged 1.6 and 1.4 percentage units higher than that on offer in the top 20 cm of Pensacola bahiagrass and Floralta limpograss swards, respectively. The CP content of herbage selected by steers grazing Pensacola bahiagrass was higher on all occasions than the minimum level required (6%) before intake is reduced by nitrogen deficiency (Minson and Milford, 1967). However, except for the first three weeks, Floralta limpograss selected was far lower in CP than the critical value.

Crude protein content of diet selected by steers was correlated (P<.01) with crude protein content (r=.65 and .81), stem bulk density (r=.54, .75) and leaf blade:stem ratio (r=.76, .64) in the top 20 cm of swards (Floralta limpograss and Pensacola bahiagrass, respectively).

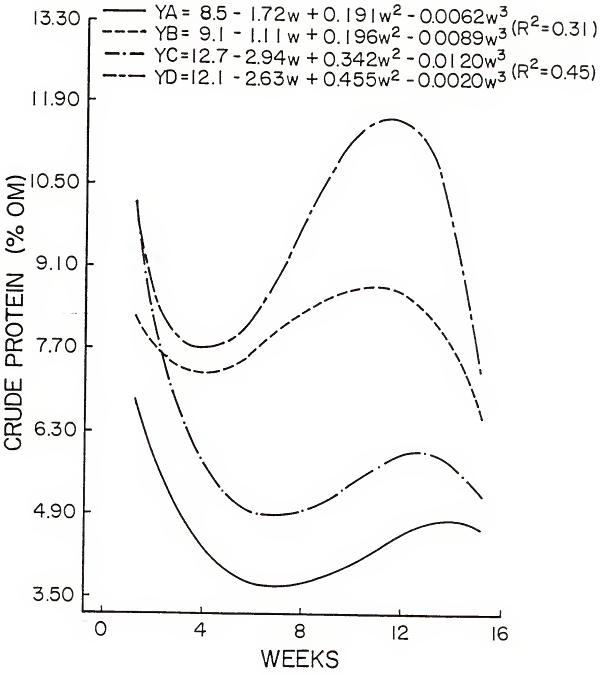

Figure 18. Crude protein content, over measurement weeks for Floralta limpograss top 20 cm sward (A), Pensacola bahiagrass top 20 cm sward (B), Floralta limpograss esophageal extrusa sample (C), Pensacola bahiagrass esophageal extrusa sample (D).

Over the season, there were increases (P<.01) in ADF and lignin content of esophageal extrusa (figures 19 and 20); however, NDF content of esophageal extrusa samples for both species was unaffected (P>.09) throughout the grazing season. Variations in cell wall constituents of extrusa samples were similar to variations in cell wall constituents in the herbage on offer in the top 20 cm of the swards of both species; but, extrusa samples were a little higher.

Increased values for NDF, ADF and lignin in the extrusa samples could be accounted for by the production of artifact lignin via the nonezymatic browning reaction. Van Soest (1965) showed that heat drying forages at temperature above 50 C resulted in increased cell wall constituents, and values were increased with the presence of moisture. Moreover, Lesparance and Bohman (1964) reported that addition of artificial saliva to hay samples followed by drying increased ADF, NDF and lignin.

Neutral detergent fiber of the Floralta limpograss selected by the steers was correlated (P<.01) with NDF content (r=.50) and green:dead ratio (r=-.69) in the top 20 cm of sward, and for Pensacola bahiagrass it was correlated (P<.01) with NDF content (r=.56) in the top 20 cm of sward.

The diet selected by steers on Pensacola had a higher proportion of leaf blade (P<.01), but similar proportion of dead matter (P<.30), and lower proportion of stem (P<.01) than the diet selected by those on Floralta limpograss (table 9). There were species by week interactions (P<.01)

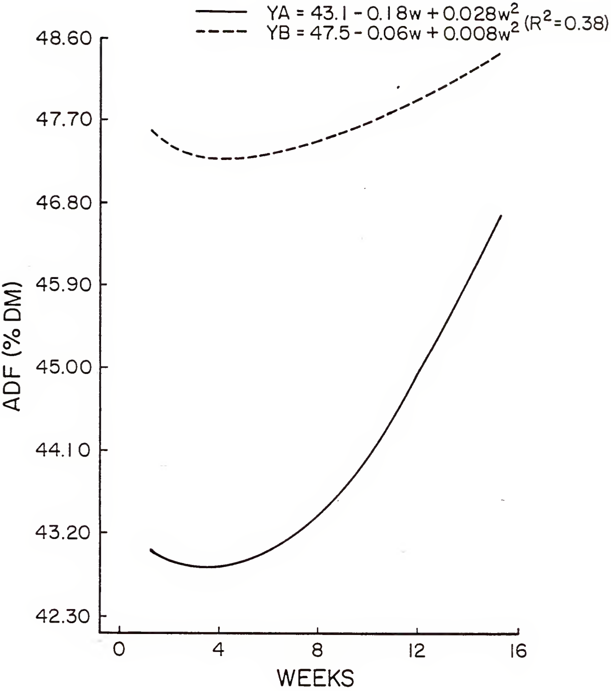

Figure 19. Acid detergent fiber (ADF) content of esophageal extrusa samples of Floralta limpograss (A) and Pensacola bahiagrass (B).

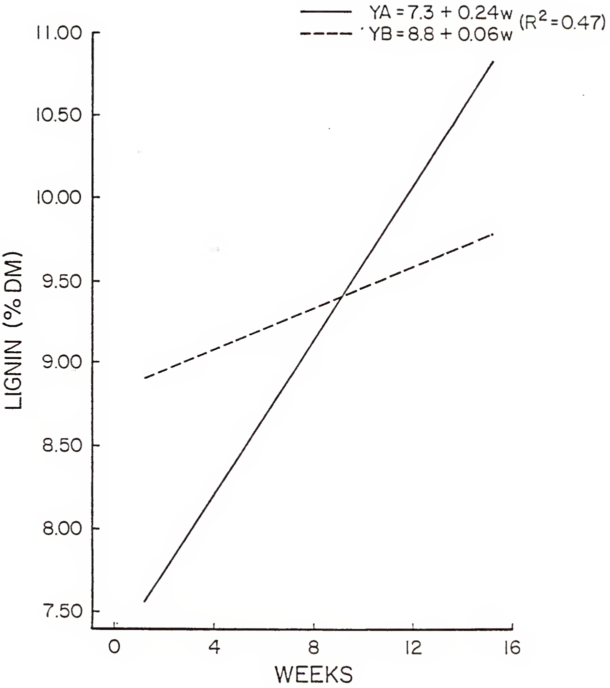

Figure 20. Lignin content of esophageal extrusa samples of Floralta limpograss (A) and Pensacola bahiagrass (B), over measurement weeks.

Table 9. Least squares means, standard errors (SE) and probabilities (P) for percentage of leaf blade, stem and dead matter contents of esophageal extrusa of steers grazing Floralta limpograss and Pensacola bahiagrass pastures

	Floralta limpograss	Pensacola bahiagrass	SE	P
Leaf Blade	38.6	68.6	.6	.01
Stem (with sheath)	52.7	18.5	.6	.01
Dead Matter	9.0	9.4	.4	.30

for percentage of leaf blade, stem, and dead matter. Individual equations are presented in figure 21.

Leaf blade percentage in the esophageal extrusa samples of animals grazing Floralta limpograss sharply decreased up to week 7, thereafter it remained almost constant to the end of the grazing season. However, little change was observed in proportion of leaf blade in the diet selected on Pensacola bahiagrass pastures through week 12, but thereafter it sharply decreased.

Percentage of leaf blade selected by cattle grazing both species was higher on all occasions than the percentage of leaf blade on offer in the top 20 cm of swards, being on average 2.3 and 4.3 times higher for Pensacola bahiagrass and Floralta limpograss, respectively.

Percentage of stem in the extrusa samples of animals grazing Floralta limpograss increased until the middle of the grazing season, thereafter it decreased. However, for Pensacola bahiagrass swards it increased slightly at the beginning, decreased in the middle, and increased again at the end of the grazing season. The proportion of stem selected by steers on both pasture species was lower than that on offer in the top 20 cm of the swards. Steers on Floralta limpograss selected, on all occasions, a diet with a higher percentage of stem than did those on Pensacola bahiagrass (figure 21).

The proportion of dead matter in the diet selected by steers increased at an increasing rate for both species over

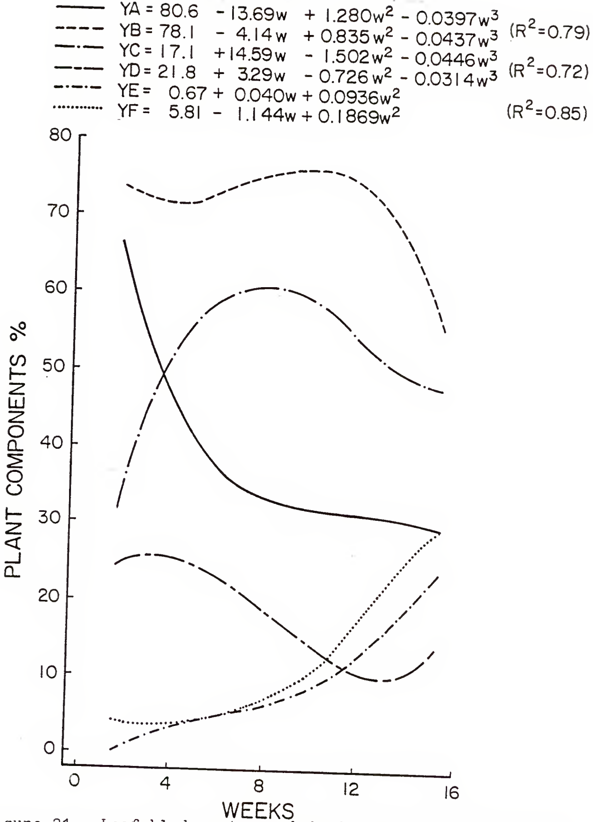

Figure 21. Leaf blade, stem and dead matter percentages of esophageal extrusa samples of Floralta limpograss (A, C and E, respectively) and Pensacola bahiagrass (B, D and F, respectively), over measurement weeks.

the grazing season. Proportion of dead matter in the top 20 cm of sward was higher over the season than the proportion in the diet selected by steers, being on average 3.4 and 3.9 times higher for Floralta limpograss and Pensacola bahiagrass, respectively. Esophageal extrusa samples from steers grazing Pensacola bahiagrass were higher in dead matter percentage on all occasions than those from steers grazing Floralta limpograss. Pensacola bahiagrass was shorter, and the top 20 cm of sward included layers that were close to the ground, thus had a higher buildup of dead matter.

It has long been recognized that the relative proportions of plant components such as dead matter, green leaf and stem within the sward canopy influence the opportunity for selection. The proportion of dead matter in the diet selected by steers was correlated ($P<0.01$) with dead matter bulk density ($r=0.87$ and 0.80) in the top 20 cm of swards (Floralta limpograss and Pensacola bahiagrass, respectively). Steers ate little dead matter when some green matter was available. They did not consume appreciable quantities of senescent herbage up to the middle of grazing season.

At the beginning of grazing season, when the quantity of green herbage was high the difference in the plant parts selected would have been the result of selection within the green matter, such as leaf in preference to stem. The proportion of leaf blade in the diet selected by steers grazing Floralta limpograss was correlated ($P<0.01$) with stem bulk density (r=-0.77), leaf blade:stem ratio (r=0.88) and green:dead matter ratio (r=0.70) in the top 20 cm of sward, but for Pensacola bahiagrass it was correlated ($P<0.03$) just with green:dead matter ratio (r=0.51) in the whole sward.

As the season progressed there were changes in the proportion of plant components of Floralta limpograss swards, such as an accumulation of stem and dead matter. However, in Pensacola bahiagrass swards the biggest change was an accumulation of dead matter throughout the season (figures 8 and 9). Thus, dead matter and/or stemmy upper surface horizons might have acted as a barrier to grazing, and steers may have been then forced to consume diets with low leaf blade contents.

These findings agree with numerous studies which have shown that grazing cattle select forage which has a chemical and botanical composition different from that on offer to the animal (Arnold, 1964; Hamilton et al., 1973; Stobbs, 1975b; Chacon and Stobbs, 1976; Hendricksen and Minson, 1980; Arnold, 1981; Milne et al., 1982). The nutritive value and proportion of plant components in the diets selected by steers with both species were generally more highly correlated with those characteristics in the top 20 cm of swards than with the sward as a whole. This suggests that steers were grazing mainly the uppermost horizons of the swards, which is in agreement with observations of Stobbs (1973b; 1975b) and Chacon et al. (1976; 1978).

Grazing Time

The time steers spent grazing both species swards varied from 534 to 662 min per 24 h period over the grazing season. Grazing time was similar ($P>.14$) for both species averaging 600 and 617 min for Pensacola bahiagrass and Floralta limpograss (table 10). Grazing times of similar lengths have been reported for cattle grazing tropical pastures (Stobbs, 1970; Chacon and Stobbs, 1976; Chacon et al., 1978).

The relationship between GT and weeks was best fitted by a quadratic equation ($P<.01$), and there were no species by week interactions ($P>.05$). There were no differences between species in the regression of species on week, and the general relationship for data from all observations pooled over species was

$$y = 533 + 21.1w - 1.31w^2 \quad (R^2=.26)$$

where y = grazing time and w = week.

The GT was short at the beginning of the grazing season, increased progressively up to the middle of the season, and decreased thereafter. Such a pattern of variation in GT is in agreement with the findings of Chacon and Stobbs (1976) and Hendricksen and Minson (1980).

Many investigators have shown a tendency for animals to extend their GT in response to a decline in BS (Stobbs, 1970; Chacon et al., 1978; Jamieson and Hodgson, 1979b; Zoby and Holmes, 1983). Several experiments have suggested, however, that when cattle grazed some tropical pastures,

Table 10. Least squares means, standard errors (SE) and probabilities (P) for jaw movements (JM), biting rate (BR), actual bites:jaw movement ratio (BJMR), total number of bites (TNB), grazing time (GT), bite size (BS) and intake for steers grazing Floralta limpograss and Pensacola bahiagrass pastures

	Floralta limpograss	Pensacola bahiagrass	SE	P
JM (no/min)	50.9	57.9	1.90	.01
BR (bites/min)	15.6	21.7	.70	.01
BJMR (%)	32.0	38.0	.02	.01
TNB (bites/24h)	9449	13365	502.20	.01
GT (min/24h)	617	600	7.80	.14
BS (g OM/bite)	1.56	1.09	.09	.01
Intake (Kg OM/24h)	13.1	13.8	1.06	.62

they did not satisfy their dry matter requirements (Topps, 1969; Prates et al., 1974; Moore et al., 1984). Thus, the extent to which cattle can alter GT to compensate for adverse sward conditions may be effective only in the early stages of the grazing period.

Stobbs (1970) suggested that fatigue limits GT to about 720 min per 24-h period. In this experiment, the peak of about 635 min per 24-h period was reached in midseason. Beyond this point, steers did not compensate for further reduction in the quality of herbage on offer by grazing longer. The decrease in GT in the second half of the season might have been due to a further adverse change in sward conditions.

Biting Rate

Biting rate was estimated by the use of automatic counters to measure jaw movements (JM) and by parallel direct counts of actual bites (AB). There was no close agreement between the measurement of grazing bites from direct observation and from automatic counter readings for both species. The ratio of AB to JM (BJMR) was always smaller than unity for both species. An average of only 32% and 38% of JM consisted of AB for Floralta limpograss and Pensacola bahiagrass, respectively (table 10).

There were differences ($P<.01$) in BJMR between the two grass species and a species by week interaction ($P<.01$). This may simply reflect differences in the mechanical process of grazing by steers on the different grass species and changes in sward condition throughout the grazing season, since there was an increase over the grazing season in BJMR on Pensacola bahiagrass swards and a decrease on Floralta limpograss swards (figure 22).

The BJMR was not correlated with any of the traits studied on Pensacola bahiagrass swards. However, on Floralta limpograss swards BJMR was correlated ($P<.01$) with stem bulk density ($r=-.59$), dead matter bulk density ($r=-.74$), green:dead matter ratio ($r=.59$), and blade:stem ratio ($r=.56$) in the top 20 cm of the sward.

Chambers et al. (1981) suggested that accuracy of measuring BR from measurements of JM may be difficult to attain when BJMR is known to vary. The results of this experiment support the above suggestion and indicate that estimates of BR, BS and intake based on JM records may be misleading, and that AB and BJMR records may give a better indication of the mechanical difficulties of prehending and harvesting mouthfuls of herbage. Based on the above results, AB records were used to calculate BR, BS and intake.

Biting rate was higher ($P<.01$) on Pensacola bahiagrass than on Floralta limpograss swards (table 10). Biting rates recorded in this experiment were substantially lower than most values previously recorded for cattle grazing tropical swards (Stobbs, 1974a, b; Chacon et al., 1976; Hendricksen and Minson, 1980). However, total jaw movements per minute averaged 58 and 51 respectively for Pensacola bahiagrass and Floralta limpograss (table 10) and these values are in

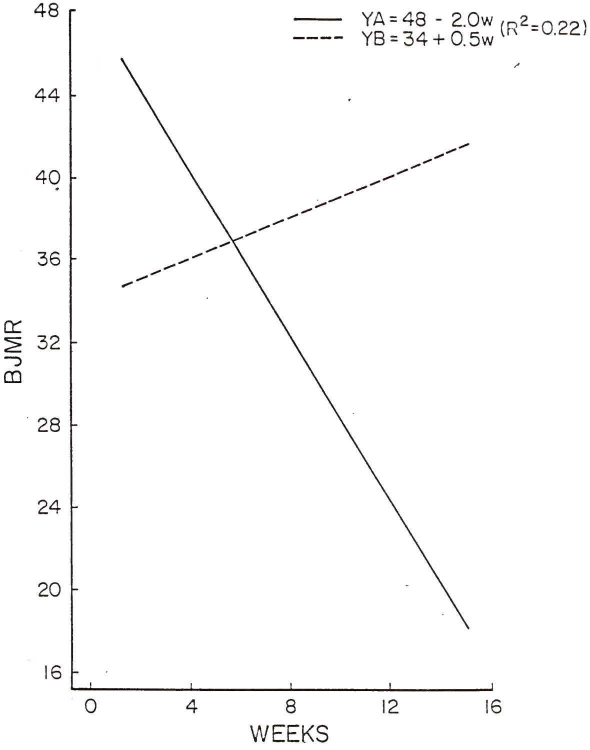

Figure 22. Actual bites:jaw movement ratio (BJMR) for esophageal fistulated steers grazing Floralta limpograss (A) and Pensacola bahiagrass (B), over measurement weeks.

agreement with those cited in the literature. One of the possible reasons for the great difference in BR recorded in this study and reported for other studies may be due to the techniques used to estimate BR. The technique used by the above authors may overestimate BR, since they recorded JM associated with manipulation of herbage before and after it was severed from the sward instead of true harvested bites.

Biting rate declined linearly over the grazing season. There were no differences between the two pasture species in regression of biting rate on week (species by week interactions, $P>.05$). The general relationship between BR and time pooled over species was

$$y = 22.9 - 0.28w \quad (R^2=0.19),$$

where y = BR and w = week in grazing season.

Both species had common slopes, but different intercepts. The intercepts were 19.6 and 26.2 for Floralta limpograss and Pensacola bahiagrass, respectively. Similarly, Stobbs (1973a), Jamieson and Hodgson (1979a), and Milne et al. (1982) observed a decreasing BR in response to limited sward conditions. However, the results obtained in this study are contrary to those reported by Stobbs (1974a), Chacon and Stobbs (1976), and Hodgson (1977), who reported an increase in BR under conditions where feed was difficult to harvest.

The total number of bites per day (TNB) on Pensacola bahiagrass was higher ($P<.01$) than on Floralta limpograss swards (table 10). There were no interactions for species and week for TNB. The TNB over the grazing season (figure 23) followed a pattern similar to that of GT, low at the beginning of grazing season, peaked at the middle of the grazing season and then declined. The decreased BR early in the grazing season was counterbalanced by increased GT. Estimates of TNB per day increased to a maximum of 12,465 and 16,389 at week six for Floralta limpograss and Pensacola bahiagrass. These values were much lower than the theoretical maximum (36,000 bites/day) proposed by Stobbs (1974a). However, total number of jaw movement averaged 33,100 per day, which is very close to the maximum bites per day proposed by the above cited author.

Bite Size

Steers were without food for 15 h prior to sampling for bite size determinations. However, there is ground for believing that there is no great effect of fasting on BS, since Chacon and Stobbs (1977) found that the effects of overnight fasting in BS were small compared with the effects of sward characteristics.

When esophageal fistulated steers are used to collect ingested herbage, practical problems are encountered due to incomplete recovery of ingested feed. To overcome this problem, the percentage of organic matter recovered was estimated for every animal at each collection period. The mean percentage of organic matter recovered was 58%, with individual samples ranging between 25 and 92%. The amount of extrusa was adjusted for percent of recovery.

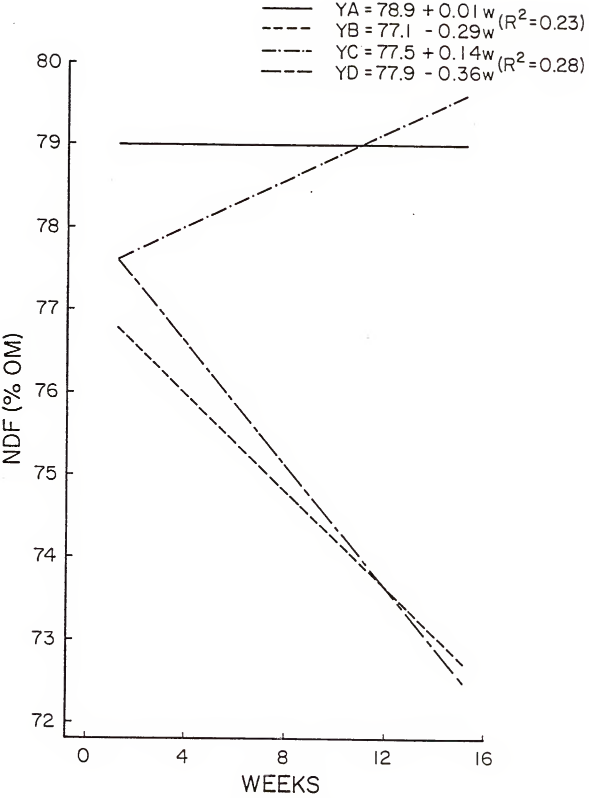

Figure 23. Total number of bites (TNB) per 24-hour period by esophageal fistulated steers grazing Floralta limpograss (A) and Pensacola bahiagrass (B), over measurement weeks.

Bite size was calculated by dividing herbage intake during the collection period by total number of AB during the same period. Bite size was greater ($P<.01$) on Floralta limpograss than on Pensacola bahiagrass (table 10). There were, however, species by week interactions ($P<.05$, figure 24). The BS on Pensacola bahiagrass swards decreased very slightly throughout the grazing season. This observation agrees with that found by Milne et al. (1982) where BS of animals grazing temperate, mixed swards did not change with changes in sward characteristics. However, BS ingested by steers grazing Floralta limpograss swards increased linearly over grazing season. This finding disagrees with several studies on tropical grasses (Stobbs, 1973a, b, 1975b; Chacon and Stobbs, 1976; Chacon et al., 1978) in which a marked decrease in BS was observed even though high quantity of herbage was available.

According to Stobbs (1975b), BS can be very small where animals pick individual leaves from a heterogeneous mass of herbage. However, there was little indication of selective grazing of this nature on Floralta limpograss swards. The BJMR for steers grazing Floralta limpograss decreased over season, and BS was negatively correlated ($P<.01$) with BJMR ($r=-.63$). However, there was no relationship between BS and BJMR on Pensacola bahiagrass. These observations suggest that, as the season progressed, steers on Floralta limpograss had changed the process of prehension of herbage.

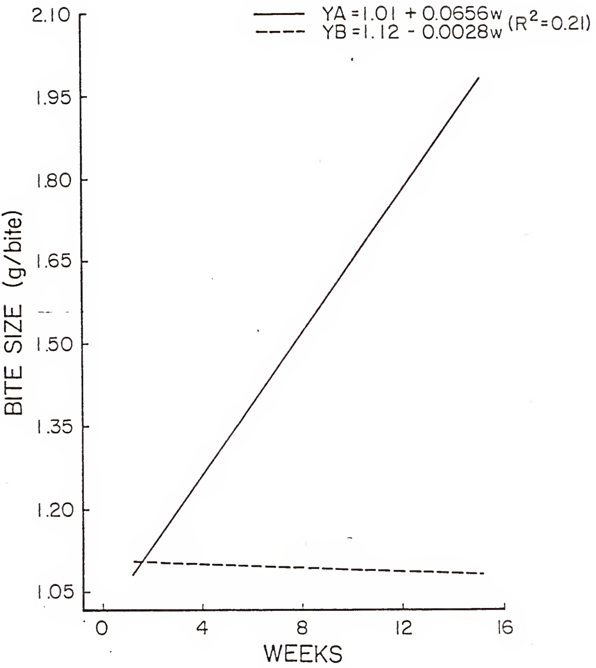

Figure 24. Bite size of esophageal fistulated steers grazing Floralta limpograss (A) and Pensacola bahiagrass (B), over measurement weeks.

They increased the manipulative movements trying to gather more herbage before severing it from the sward. This resulted in an increased BS. Steers on Pensacola bahiagrass did not make nearly as much change in BJMR or BS.

Several studies with tropical grasses (Stobbs, 1973b, 1974b, 1975b; Chacon et al., 1976, 1978; Chacon and Stobbs, 1976; Ludlow et al., 1982) have shown that BS ranged from .13 to .51 g OM per bite. However, in this study mean BS was much higher than values reported before, averaging 1.09 and 1.56 g OM per bite for Pensacola bahiagrass and Floralta limpograss, respectively (table 10). Differences in techniques used to estimate BS may be one of the reasons for this difference. Others have calculated BS from total number of grazing JM, which included harvesting bites as well as JM associated with the manipulation of herbage before and after it was severed from the sward. Thus, there is reason to believe that they underestimated BS due to an overestimation of BR. In this study, when BS was estimated from total JM, it averaged .39 and .43 g OM per bite, respectively, on Pensacola bahiagrass and Floralta limpograss, and these values agree with BS reported in the literature for tropical grasses.

Intake

Herbage intake was estimated as the product of time spent grazing, number of bites per unit of time and average size of each bite. The estimated mean daily OM intakes by steers grazing the two grass species did not differ (P>.63), and were 13.1 kg for steers grazing Floralta limpograss and 13.8 kg for those grazing Pensacola bahiagrass (table 10). There were no significant (P>.05) species by week interactions. Thus, there was no significant difference in the regression of intake on week between species, and the general relationship from all observations pooled over species is presented in figure 25. Intake increased up to the middle of grazing season, reaching a maximum of about 15 kg OM per day, and then declined progressively.

Biting rate on both grass species declined progressively over the season, indicating that more difficult grazing conditions apparently imposed limitations on the rate at which steers could ingest their feed. A greater degree of selection exerted by the animals also could be related to the lower BR. However, in an attempt to compensate for this decline in BR, there was a steady increase in GT by steers on both grass species during the first half of grazing season. The ability of the steers to make compensating changes in GT was limited, and during the last half of grazing season GT decreased progressively, thus, estimated herbage intake also declined.

Bite size on Pensacola bahiagrass swards was almost constant over the grazing season, but on Floralta limpograss it increased. Such an increase was not large enough, however, to compensate for the observed reduction in BR, BJMJ and GT. Thus, in the later stages of the grazing

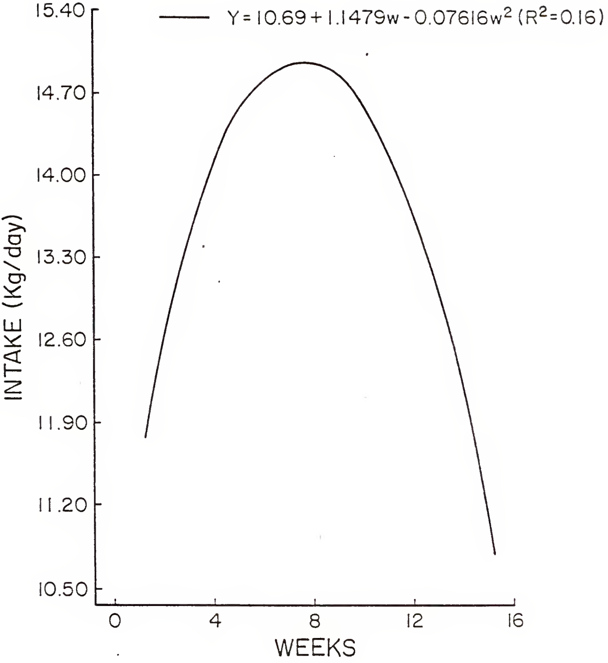

Figure 25. Organic matter intake by esophageal fistulated steers over measurement weeks, Floralta limpograss and Pensacola bahiagrass combined.

season, estimated herbage intake on Floralta limpograss also declined sharply.

These results support the evidence from other studies (Stobbs, 1970, 1973a, 1974a, b; Jamieson and Hodgson, 1979a; Zoby and Holmes, 1983) that animals are able to modify their grazing behavior to maintain level of intake. In this study, however, the compensation was effective only in the early stages of the grazing season. These results confirm observations reported by many others (Allden and Whittaker, 1970; Chacon and Stobbs, 1976; Chacon et al., 1978; Jamieson and Hodgson, 1979b; Hendricksen and Minson, 1980).

Absolute intake values estimated in this experiment were somewhat higher than those usually recorded with cattle grazing on tropical swards (Prates et al., 1974; Oyenuga and Olubajo, 1975). The mean daily estimated dry matter (DM) intake based on average weight of the esophageal fistulated steers and on weight change measured on the tester steers during the grazing season was 9 kg DM per steer (NRC, 1976). This estimated daily intake was much lower than the 13.1 and 13.8 kg OM estimated from eating behavior components (table 10).

Research data have shown that average daily DM intakes vary with type of diet and body weight, age and condition of animal. Mature, moderately fat cattle may consume amounts of DM equal to as low as 1.4% of their live weight, whereas thin, yearling cattle may consume amounts equal to 3% of their live weight (NRC, 1976). The steers used in this study were mature and in moderate condition, thus, their average daily DM intake expressed as a percent of live weight was probably between the two values given by NRC (1976). The mean, daily intakes estimated from components of eating behavior (13.1 and 13.8 kg OM) are equal to intakes of 14.6 and 15.3 kg DM (OM/.90). These values are above the maximum intake values cited by NRC (3%), since the average live weight of steers was 400 kg. Thus, data indicate that estimated intake based on eating behavior components resulted in an overestimation of intake.

The overestimation of intake probably could have been the consequence of overestimating BS, since (Stobbs, 1973a; Hodgson, 1981) stated that GT and BR are more precisely determined under extensive conditions. Bite size might have been overestimated, since it was corrected by a recovery factor calculated from hand-fed, chopped forage, which might not represent the herbage recovery from the esophageal fistula under grazing conditions. Moreover, BS was shown to be the major factor influencing estimated intake (table 11).

Although Chacon and Stobbs (1976) have shown that it is technically possible to estimate herbage intake from information on the components of ingestive behavior, in the current experiment the eating behavior parameters, mainly BS, were not precise enough to predict animal intake, and it was considered to be an unreliable method of estimating intake. This agrees with a suggestion made by Hodgson (1982) that measurements of eating behavior should be used as a means of explaining observed effects on herbage intake rather than as means of estimating intake itself.

Except for grazing time, all eating behavior components and estimated intake varied greatly (P<.01) between steers grazing the same species swards. However, there was little evidence (P>.05) of variation in the time of sampling (AM vs PM), so that BS, BR and selectivity of grazing steers could be estimated in any main period of grazing.

Correlation Among Eating Behavior Components

Eating behavior components (BR, BS, GT) for both grass species were positively correlated with estimated intake, except for BR on Floralta limpograss pastures (table 11). The correlation coefficients among all eating behavior components and changes in herbage intake were greater for Pensacola bahiagrass than for Floralta limpograss pastures.

Bite size was the major factor influencing estimated herbage intake. The correlation coefficients for herbage intake on bite size were .60 and .88 for Floralta limpograss and Pensacola bahiagrass, respectively. This observation is in agreement with that reported by Chacon and Stobbs (1976), Chacon et al. (1976), and Hendricksen and Minson (1980).

Biting rate decreased (P<.01) with increasing BS on Floralta limpograss and with decreasing GT on Pensacola bahiagrass (table 11). A negative correlation between BS and BR also was reported by Allden and Whittaker (1970), Stobbs (1974b), Chacon and Stobbs (1976), Chacon t al. (1978), Jamieson and Hodgson (1979a, b), Hodgson (1981) and

Table 11. Correlation coefficients and probabilities (P) among eating behavior components measured as bite size (BS), biting rate (BR), grazing time (GT), total number of bites (TNB) and intake (INT) for Floralta limpograss and Pensacola bahiagrass pastures.

	Floralta limpograss				Pensacola bahiagrass			
	BS	BR	GT	TNB	BS	BR	GT	TNB
BR	-.74				-.01			
P	.01				.95			
GT	.25	.07			.32	.74		
P	.21	.70			.11	.01		
TNB	-.54	.79	.29	.05	.73	.60		
P	.03	.01	.28	.85	.01	.02		
INT	.60	.31	.40	.57	.88	.59	.65	.29
P	.01	.12	.04	.02	.01	.02	.01	.30

Milne et al. (1982). Jamieson and Hodgson (1979a, b) and Zoby and Holmes (1983) also reported a positive correlation between BR and GT.

These correlations suggest that to maintain the required intake over the season, steers grazing Floralta limpograss altered their eating behavior from that of steers grazing Pensacola bahiagrass pastures.

Animal Performance

Mean live weights of steers grazing both grass species were similar (P<.92). However, there were species by week interactions (P<.01) for live weight of steers. In spite of live weight of steers grazing both grass species increased at decreasing rate during the grazing season, the changes over the season were different between grass species (figure 26).

Daily gains of steers grazing both grass species were similar (P>.92), averaging .36 and .27 kg respectively for Pensacola bahiagrass and Floralta limpograss. Low daily gains have been reported previously for Pensacola bahiagrass (Prates et al., 1974) and for Floralta limpograss (Quesenberry et al., 1984). Stobbs (1974c) reviewed animal performance from grazing experiments in the tropics and showed that mean annual gains were .35 kg per steer per day. Smith (1970) observed that tropical pastures were capable of producing good gains over a relatively short period, which was during the early growing season. These findings agree with the pattern of growth observed in this

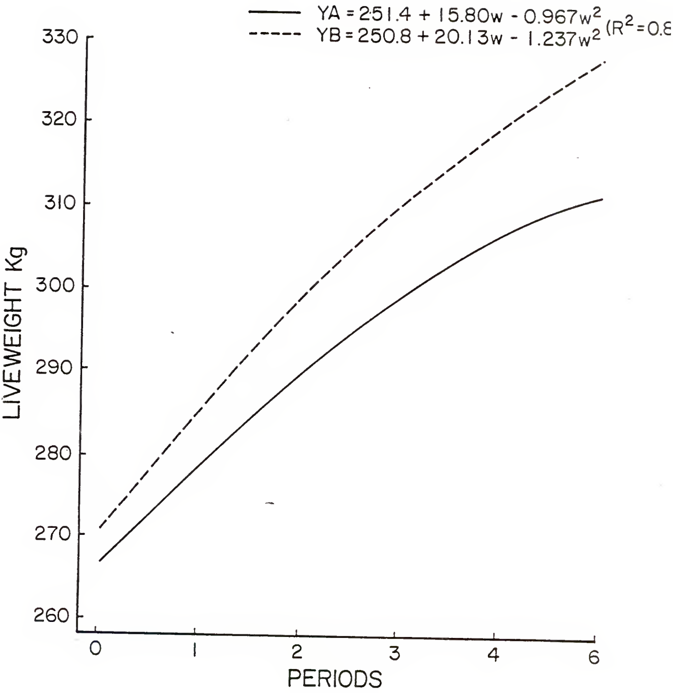

Figure 26. Live weight curve, over the five 28-day periods, of steers grazing Floralta limpograss (A) and Pensacola bahiagrass (B).

experiment. Such a decrease in daily gain over the grazing season was due to the decline in nutritive value and in intake in response to changes in sward characteristics associated with accumulation of mature forage.

Summary and Conclusions

A continuous grazing experiment was conducted from June to October, 1982, to study changes in steer eating behavior components over the grazing season, for Floralta limpograss (Hemarthria altissima) and Pensacola bahiagrass (Paspalum notatum), and to relate these changes to intake and steer performance.

Grazing time was recorded with vibracorders over 24-h periods. Biting rate was recorded by visual observation and total jaw movements by electronic counter, both over 20-min periods. Bite size was estimated from biting rate over the time interval and organic matter weight of the corresponding esophageal extrusa. Daily organic matter intake was estimated as the product of grazing time, bite size and biting rate. Live weight of tester steers was recorded every 28 days.

The eating behavior components measured in each period consisted of grazing time, bite size, biting rate and organic matter intake. Crude protein, neutral detergent fiber, acid detergent fiber, lignin, in vitro organic matter digestibility and proportions of leaf blade, stem and dead matter in the extrusa samples also were obtained each period.

The results of this study permit the following conclusions:

1. Steers grazing both grass species showed preference for green herbage rather than dead and for leaf rather than stem. Moreover, the diet selected was higher in crude protein and in vitro digestibility than was the herbage on offer, both in the whole sward and in the top 20 cm.
2. Relative values for estimated intake were similar for both species. Intake increased up to the middle of grazing season and thereafter decreased rapidly. Steers grazing Floralta limpograss altered their eating behavior by increasing BS over the grazing season in an attempt to maintain intake, whereas those on Pensacola bahiagrass did not alter their eating behavior to compensate for adverse sward conditions.
3. In order to maintain greater levels of intake on both species, steers modified their eating behavior, increasing the total number of bites prehended. However, this compensation was effective only in the early stages of the grazing season, since the total number of bites and also intake decreased in the late season.
4. Steers on both grass species had similar average daily gains. However, average daily gain of steers on Floralta limpograss was less than might have

been expected, since the intake of both grass species was equal and Floralta limpograss was more digestible. The lower crude protein content of the diet selected from the Floralta limpograss sward might account for the lack of a higher daily gain by steers grazing this species.

5. Among eating behavior components, bite size was shown to be the major factor influencing estimated herbage intake by steers on both grass species.
6. Estimated intake based on eating behavior components did not provide accurate absolute intake values. However, the eating behavior measurements provided a useful basis for explaining the effect of variations in the sward characteristics on changes in herbage intake over the grazing season.

CHAPTER 5
GENERAL DISCUSSION AND CONCLUSIONS

A crude protein content of less than 6% in the diet can drastically reduce intake (Minson and Milford, 1967). Except for the first three weeks, steers on Floralta limpograss pastures selected diets below this critical level, so the steers probably were protein-deficient. If nitrogen is not the limiting factor, the distention mechanism is one factor that could control intake of herbage by ruminants (Balch and Campling, 1962). However, marked changes in eating behavior were observed throughout the grazing season, which suggests that steers were attempting to maintain the required intake. There were marked changes in sward structure over the season, and these changes may have been related to eating behavior.

The major sward components correlated with eating behavior measurements on Floralta limpograss pastures were: GT with leaf blade:stem ratio in the top 20 cm of sward (r=-.58), BR with organic matter bulk density in the top 20 cm of sward (r=-.52), and BS with leaf blade bulk density in the whole sward (r=.64). But estimated intake and daily gain were not correlated with any single component studied. However, on Pensacola bahiagrass the eating behavior measurements and estimated intake were not correlated with any single sward component studied, but daily gain was negatively correlated with dead matter bulk density in the top 20 cm of sward (r=-.55).

These findings suggest that sward components were not independent enough to achieve a clear indication of the magnitude of their separate effects on eating behavior measurements, intake, and daily gain. Thus, several sets of combinations among sward components were tested and the best fitting multiple regression equation obtained for each trait studied is presented in table 12. Arnold (1981) stated that the plant components measured in conventional proximate analysis cannot influence eating behavior directly because they are not chemical entities active at the molecular level. Therefore, these components were not used in the prediction equations.

Grazing time on Floralta limpograss increased with decreasing leaf blade:stem ratio in the top 20 cm of sward and leaf blade bulk density in the whole sward and with increasing organic matter bulk density in the whole sward (R=.71). Grazing time on Pensacola bahiagrass increased with increasing organic matter bulk density and with decreasing leaf blade bulk density in the whole sward (R=.62).

Grazing time for both species increased to the middle of grazing season and decreased thereafter. The increase in GT on Floralta limpograss, that occurred during the first

TABLE 12. Multiple regression equations and probabilities (P) for predicting grazing time (GT), biting rate (BR), bite size (BS), intake (INT), and daily liveweight gain (LW) from sward characteristics of Floralta limpograss and Pensacola bahiagrass.[a]

Prediction Equation[b]	P
Floralta limpograss	
GT = 609 - 157(TLBSR) + 7(OMBD) - 7 (LBBD)	.04
BR = 22.96 - .002(TOMBD) + .015 (TLBBD)	.04
BS = 1.69 - .008(TSBD) - .001(TGDR) + 0.054(LBBD)	.01
INT = 10.11 - .037(TDMBD) + .004(TLBBD) - 0.020(TGDR)	.06
ADG = .5025 + .0005(TOMBD) - .0333(TGBD) + 0.0111(TGDR)	.07
Pensacola bahiagrass	
GT = 582 + 1.2(OMBD) - 1.2(LBBD)	.05
BR = 22.96 - .002(TOMBD) + .015(TLBBD)	.04
BS = 1.0268 + .0066(TGBD) - .0001(TLBBD)	.06
INT = 10.47 - .018(TOMBD) - .001(TLBBD) + .332(TGBD) + 1.2961 (LBBD)	.08
ADG = .6286 - .0922(TDMBD) + .0242(TLBSR)	.03

[a] Sward Characteristics: OMBD - Organic matter bulk density of the whole sward; LBBD - Leaf blade bulk density of the whole sward; TOMBD - Organic matter bulk density in the top 20 cm of sward; TLBBD - Leaf blade bulk density in the top 20 cm of sward; TLBSR - Leaf blade:stem ratio in the top 20 cm of sward; TGBD - Green matter bulk density in the top 20 cm of sward; TDMBD - Dead matter bulk density in the top 20 cm of sward; TSBD - Stem bulk density in the top 20 cm of sward; TGDR - Green:dead matter ratio in the top 20 cm of sward.

[b] The use of any additional sward component did not improve the fit of regression.

half of the grazing season, might be explained by a decline in leaf blade bulk density in the whole sward and a decrease in leaf blade:stem ratio in the top 20 cm of sward. As a consequence, steers were selecting only the most desirable parts of plants, which implied that it took them longer to satisfy their appetites. In spite of an increase in organic matter bulk density in the whole sward of both grass species, in the first weeks of the second half of the grazing season the GT decreased. Part of this decrease in GT might have been a consequence of an increase in leaf blade bulk density and leaf blade:stem ratio in the latter part of the grazing season. However a high percentage of the OM available to the steers was dead matter, and the percentage of dead matter increased over the grazing season. Also, OM intake decreased during the second half of grazing season. This might indicate a decrease in the palatability of the material on offer. A decrease in palatability of plant material available to the animal probably would affect intake and could cause modifications in eating behavior, such as decrease in GT. Palatability changes in the swards over the grazing period and the effects of these changes on grazing behavior, intake and animal performance should be studied.

Biting rate for both species increased with decreasing organic matter bulk density and increasing leaf blade bulk density in the top 20 cm of swards (R=.64). The multiple regression equation was the same for both species. The equation suggests that increased leafiness in grazed horizons would tend to increase BR, while BR would decrease as OM on offer become more dense. However, in this study there was an increase in leaf blade bulk density in the top 20 cm of both grass swards over the grazing season, and during the same time period there was a decrease in BR. Since green matter and leaf blade were the major components of the diet selected by steers, this decrease in BR might have been due to the inaccessibility of the leaf blade as a consequence of a buildup of dead matter and/or stem in mature pasture.

Bite size on Floralta limpograss increased with decreasing stem bulk density and green dead matter ratio in the top 20 cm of sward, and with increasing blade bulk density in the whole sward (R=.80). Bite size on Pensacola bahiagrass decreased with increasing leaf blade bulk density and with decreasing green matter bulk density in the top 20 cm of sward (R=.61). The relationship between the sward components and the size of bite harvested emphasize the importance of leaf blade and green matter to the grazing animals.

Estimated intake of Floralta limpograss increased with decreasing dead matter bulk density and green:dead matter ratio, and with increasing leaf blade bulk density in the top 20 cm of sward (R=.69). Estimated intake of Pensacola bahiagrass increased with decreasing organic matter bulk density and leaf blade bulk density in the top 20 cm of sward, and with increasing leaf blade bulk density in the whole sward and green matter bulk density in the top 20 cm of sward (R=.56). The most likely reason for the decline in the amount of herbage intake for both species over the last half of the grazing season was an increase in dead matter bulk density. Even when large quantities of herbage were available, steers on mature pasture had difficulty in satisfying their nutrient requirements, maybe as a consequence of the inaccessibility of leaf blade on offer.

Daily gain on Floralta limpograss increased with decreasing green matter bulk density and with increasing organic matter bulk density and green:dead matter ratio in the top 20 cm of sward (R=.58). Daily gain on Pensacola bahiagrass increased with decreasing dead matter bulk density and with increasing leaf blade:stem ratio in the top 20 cm of sward (R=.70). Such observations agree with other studies which have shown that when pasture contains a seasonally variable amount of dead matter, the relationship between herbage available and animal performance applies only to the green fraction of the pasture (Willoughby, 1959; Chacon et al., 1978; Mannetje and Ebersohn, 1980).

Sward components were not independent enough to permit determination of the magnitude of their separate effects on eating behavior components, estimated intake, and animal liveweight gain. A combination of two or more sward components explained most of the variation of eating behavior components, estimated intake, and liveweight gain.

APPENDIX

Table A1. Analysis of variance for quantity of organic matter on offer in the whole sward.

Source	DF	SS	P
Grass (G)	1	4528385	.01
Week (W)	1	635142	.01
W X W	1	427530	.01
Error	128	3297802	-

Table A2. Analysis of variance of organic matter bulk density distribution within stratified layers.

Source[a]	DF	SS	P
Grass (G)	1	66.68	-
Week (W)	1	15.83	-
W X W	1	.13	-
Layer (L)	5	274.98[a]	.04
G X L	3	97.89	.24
G X L X W	8	1108.90	.01
G X L X W X W	8	3782.13[b]	.01
Error	209	4875.82	-

[a] The random effect of site within grass was absorbed.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A3. Analysis of variance for organic bulk density in the whole sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week (W)	2	1598.1	.01
G X W X W	2	342.6[b]	.01
Error	126	3073.8	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A4. Analysis for organic matter bulk density in the top 20 cm of sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week	2	662[b]	.01
Error	128	16503	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A5. Analysis of variance for quantity of leaf blade on offer in the whole sward.

Source	DF	SS	P
Grass	1	47042	.01
Week	1	1776	.12
Error	129	95991	-

Table A6. Analysis of variance for leaf blade bulk density distribution within stratified layers.

Source[a]	DF	SS	P
Grass (G)	1	154.0	-
Week (W)	1	14.6	-
Layer (L)	5	58.1	.01
G X L	3	63.3	.01
Error	225	276.4	-

[a] The random effect of site within grass was absorbed.

Table A7. Analysis of variance for leaf blade bulk density in the whole sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week (W)	2	22.8	.01
G X W X W	2	38.8[b]	.01
Error	126	142.9	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A8. Analysis of variance for leaf blade bulk density in the top 20 cm of sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week	2	52.9[b]	.01
Error	128	488.5	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A9. Analysis of variance for quantity of leaf sheath on offer in the whole sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week	2	1172[b]	.01
Error	128	18711	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A10. Analysis of variance for leaf sheath bulk density distribution within stratified layers.

Source[a]	DF	SS	P
Grass (G)	1	1.70	-
G X Week (W)	2	2.21	-
Layer (L)	5	55.72	.01
G X L	3	47.18	.01
Error	221	65.85	-

[a] The random effect of site within grass was absorbed.

Table A11. Analysis of variance for leaf sheath bulk density in the top 20 cm of sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week	2	8.83[b]	.01
Error	128	104.30	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A12. Analysis of variance for quantity of stem on offer in the whole sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week (W)	2	506028	.01
G X W X W	2	241299[b]	.01
Error	124	1499164	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A13. Analysis of variance for stem bulk density distribution within stratified layers.

Source[a]	DF	SS	P
Grass (G)	1	105.9	-
G X Week (W)	2	56.7	-
G X W X W	2	174.1	-
Layer (L)	5	28.8	.82
G X L	3	1.3	.98
G X L X W	8	716.9	.01
G X L X W X W	8	1503.2[b]	.01
Error	189	2477.7	-

[a] The random effect of site within grass was absorbed.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A14. Analysis of variance for stem bulk density in the top 20 cm of sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week (W)	2	1699.9	.01
G X W X W	2	1048.7[b]	.01
Error	126	3180.9	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A15. Analysis of variance for quantity of dead matter on offer in the whole sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week (W)	2	88600	.01
G X W X W	2	42737[b]	.01
Error	126	448528	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A16. Analysis of variance for dead matter bulk density distribution within stratified layers.

Source[a]	DF	SS	P
Grass (G)	1	15.4	-
G X Week (W)	2	23.5	-
G X W X W	2	28.0	-
Layer (L)	5	47.5	.11
G X L	3	63.2	.01
G X L X W	8	112.3	.01
G X L X W X W	8	799.6[b]	.01
Error	183	1141.5	-

[a] The random effect of site within grass was absorbed.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A17. Analysis of variance for dead matter bulk density in the top 20 cm of sward.

Source	DF	SS	P
Grass	1	7.7	.63
Week	1	4671.2	.01
Error	129	4280.3	-

Table A18. Analysis of variance for sward height.

Source	DF	SS	P
Grass	1	3131	.01
Week	1	4526	.01
Error	129	15888	-

Table A19. Analysis of variance for percentage of protein content in the herbage on offer in the whole sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week (W)	2	18.1	.01
G X W X W	2	19.2	.01
G X W X W X W	2	16.7[b]	.01
Error	124	179.8	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A20. Analysis of variance for crude protein distribution within stratified layers.

Source[a]	DF	SS	P
Grass (G)	1	5.9	-
G X Week (W)	2	16.9	-
G X W X W	2	3.6	-
G X W X W X W	2	16.7	-
Layer (L)	5	15.8	.01
G X L	3	9.6	.01
G X L X W	8	16.5	.01
G X L X W X W	8	10.7	.01
G X L X W X W X W	8	63.6[b]	.01
Error	201	112.3	-

[a] The random effect of site within grass was absorbed.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A21. Analysis of variance for crude protein content in the herbage in the top 20 cm of sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week (W)	2	36.27	.01
G X W X W	2	29.00	.01
G X W X W X W	2	38.61[b]	.01
Error	124	188.06	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A22. Analysis of variance for in vitro organic matter digestibility in the herbage on offer in the whole sward.

Source	DF	SS	P
Grass	1	2948	.01
Week (W)	1	373	.01
W X W	1	51	.01
Error	128	847	-

Table A23. Analysis of variance for in vitro organic matter digestibility distribution within stratified layers.

Source[a]	DF	SS	P
Grass (G)	1	5980	-
Week (W)	1	985	-
W X W	1	185	-
Layer (L)	5	2244	.01
G X L	3	184	.01
Error	224	1333	-

[a] The random effect of site within grass was absorbed.

Table A24. Analysis of variance for in vitro organic matter digestibility of the herbage in the top 20 cm of sward.

Source	DF	SS	P
Grass	1	3749	.01
Week (W)	1	444	.01
W X W	1	71	.01
Error	128	1032	-

Table A25. Analysis of variance for neutral detergent fiber content in the herbage on offer in the whole sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week	2	47.1[b]	.01
Error	116	289.9	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A26. Analysis of variance for neutral detergent fiber distribution within stratified layers.

Source[a]	DF	SS	P
Grass (G)	1	48.2	-
G X Week	2	94.7	-
Layer (L)	5	128.8	.01
G X L	3	213.1	.01
Error	201	336.5	-

[a] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A27. Analysis of variance for neutral detergent content in the herbage in the top 20 cm of sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week	2	123.5[b]	.01
Error	115	376.7	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A28. Analysis of variance for acid detergent fiber content in the herbage on offer in the whole sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week	2	45.8[b]	.01
Error	116	198.5	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A29. Analysis of variance for acid detergent fiber distribution within stratified layers.

Source[a]	DF	SS	P
Grass (G)	1	48.2	-
G X Week	2	94.7	-
Layer (L)	5	310.9	.01
G X L	3	356.3	.01
Error	201	336.5	-

[a] The random effect of site within grass was absorbed.

Table A30. Analysis of variance for acid detergent fiber content in the herbage in the top 20 cm of sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week	2	287.6[b]	.01
Error	115	277.6	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A31. Analysis of variance for lignin content in the herbage on offer in the whole sward.

Source	DF	SS	P
Grass (G)	1	-	.01[a]
G X Week (W)	2	32.6	.01
G X W X W	2	26.5[b]	.01
Error	114	94.7	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A32. Analysis of variance for lignin distribution in stratified layers of swards.

Source[a]	DF	SS	P
Grass (G)	1	18.0	-
G X Week (W)	2	52.2	-
G X W X W	2	13.1	-
Layer (L)	5	326.5	.01
G X L	3	61.8	.01
Error	201	84.3	-

[a] The random effect of site within grass was absorbed.

Table A33. Analysis of variance for lignin content in the herbage in the top 20 cm of swards.

Source	DF	SS	P
Grass (G)	1	-	.05[a]
G X Week (W)	2	50.5	.01
G X W X W	2	49.5[b]	.01
Error	113	112.5	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A34. Analysis of variance for in vitro organic matter digestibility of esophageal extrusa samples

Source	DF	SS	P
Grass (G)	1	-	.01[a]
Time (T)	1	22.1	.16
Animal (A)	3	1.0	.98
T X A	3	19.4	.62
G X T	1	1.4	.74
G X Week	2	56.6[b]	.01
Error	95	1083.4	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A35. Analysis of variance for crude protein content of esophageal extrusa samples

Source	DF	SS	P
Grass (G)	1	-	.01[a]
Time (T)	1	1.47	.44
Animal (A)	3	18.92	.06
T X A	3	3.22	.74
G X T	1	.10	.84
G X Week (W)	2	36.40	.01
G X W X W	2	56.54	.01
G X W X W X W	2	91.63[b]	.01
Error	91	241.89	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A36. Analysis of variance for neutral detergent fiber content of esophageal extrusa samples

Source	DF	SS	P
Grass (G)	1	118.3	.09
Time (T)	1	31.1	.38
Animal (A)	3	58.8	.70
T X A	3	111.9	.43
G X T	1	90.1	.14
Week	1	.7	.90
Error	98	4081.1	-

Table A37. Analysis of variance for acid detergent fiber content of esophageal extrusa samples

Source	DF	SS	P
Grass (G)	1	-	.01[a]
Time (T)	1	.01	.97
Animal (A)	3	5.45	.33
T X A	3	1.94	.75
G X T	1	2.11	.25
G X Week (W)	2	1.84	.57
G X W X W	2	24.77[b]	.01
Error	95	153.18	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A38. Analysis of variance for lignin content of esophageal extrusa samples

Source	DF	SS	P
Grass (G)	1	-	.25[a]
Time (T)	1	1.99	.10
Animal (A)	3	7.63	.02
T X A	3	.74	.81
G X T	1	.01	.90
G X Week	2	16.14[b]	.01
Error	97	69.14	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A39. Analysis of variance for percentage of leaf blade of esophageal extrusa samples

Source	DF	SS	P
Grass (G)	1	-	.01[a]
Time (T)	1	24.8	.28
Animal (A)	3	39.8	.60
T X A	3	5.2	.96
G X T	1	15.7	.39
G X Week (W)	2	1393.4	.01
G X W X W	2	792.9	.01
G X W X W X W	2	2921.7[b]	.01
Error	95	2008.1	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A40. Analysis of variance for percentage of stem (stem plus leaf sheath) of esophageal extrusa samples

Source	DF	SS	P
Grass (G)	1	-	.01[a]
Time (T)	1	26.5	.25
Animal (A)	3	42.9	.55
T X A	3	3.5	.97
G X T	1	13.3	.42
G X Week (W)	2	1532.1	.01
G X W X W	2	958.5	.01
G X W X W X W	2	2846.0[b]	.01
Error	95	1924.7	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A41. Analysis of variance for percentage of dead matter of esophageal extrusa samples

Source	DF	SS	P
Grass (G)	1	-	.30[a]
Time (T)	1	.2	.89
Animal (A)	3	30.3	.47
T X A	3	9.7	.84
G X T	1	1.8	.70
G X Week (W)	2	59.6	.06
G X W X W	2	118.4[b]	.01
Error	91	1081.9	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A42. Analysis of variance for grazing time

Source	DF	SS	P
Grass (G)	1	3525	.14
Animal (A)	3	8849	.15
Week (W)	1	23888	.01
W X W	1	24696	.01
Error	43	70629	-

Table A43. Analysis of variance for biting rate

Source	DF	SS	P
Grass (G)	1	1025.4	.01
Time (T)	1	78.2	.08
Animal (A)	3	508.6	.01
T X A	3	56.8	.55
G X T	2	8.6	.57
Week	2	156.4	.01
Error	96	2665.3	-

Table A44. Analysis of variance for jaw movements

Source	DF	SS	P
Grass (G)	1	-	.01[a]
Time (T)	1	1342	.01
Animal (A)	3	1937	.03
T X A	3	86	.93
G X T	1	474	.14
G X Week (W)	2	1443	.04
G X W X W	2	17035[b]	.05
Error	88	19417	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A45. Analysis of variance for actual bites:jaw movements ratio

Source	DF	SS	P
Grass (G)	1	-	.01[a]
Time (T)	1	.02	.46
Animal (A)	3	.03	.65
T X A	3	.02	.75
G X T	1	.01	.57
G X Week	2	.24[b]	.01
Error	94	1.44	.01

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A46. Analysis of variance for total number of bites per 24 h

Source	DF	SS	P
Grass	1	196872230	.01
Animal	3	97174527	.01
Week (W)	1	15658715	.12
W X W	1	29310529	.03
Error	43	285140146	-

Table A47. Analysis of variance for bite size

Source	DF	SS	P
Grass (G)	1	-	.01[a]
Time (T)	1	.02	.29
Animal (A)	3	6.18	.01
A X T	3	.98	.50
G X T	1	.04	.76
G X Week	2	23.00[b]	.01
Error	94	40.21	-

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A48. Analysis of variance for intake

Source	DF	SS	P
Grass	1	6.9	.62
Animal	3	473.1	.01
Week (W)	1	69.9	.12
W X W	1	83.7	.09
Error	43	1298.9	-

Table A49. Analysis of variance for daily gain

Source	DF	SS	P
Grass	1	-	.50[a]
Steer (Grass)	22	46903.98	.01
Grass X Period	2	5738.82	.01
Grass X Period X Period	2	1044.45[b]	.01
Error	116	8651.45	.01

[a] Not estimated by program, probability level obtained from t-table.

[b] Difference in the residual sum of squares when fitting two models, pooled and individual.

Table A50. Correlation coefficients and probabilities (P) among eating behavior measured as bite size (BS), biting rate (BR), grazing time (GT), intake (INT) and sward characteristics[a] of the whole and top 20 cm of Floralta limpograss

	Whole sward				Top 20 cm sward			
	BS	BR	GT	INT	BS	BR	GT	INT
OMBD	0.48	-0.52	0.43	0.04	0.56	-0.52	0.43	0.07
P	0.07	0.04	0.15	0.98	0.03	0.04	0.15	0.82
LBBD	0.64	-0.59	0.28	-0.17	0.56	-0.21	-0.26	0.01
P	0.01	0.02	0.31	0.54	0.03	0.44	0.35	0.99
SBD	0.18	-0.29	0.53	0.14	0.33	-0.32	0.46	0.18
P	0.52	0.30	0.04	0.60	0.22	0.24	0.08	0.51
SDE	0.59	-0.60	0.14	-0.17	0.58	-0.60	0.18	-0.08
P	0.02	0.02	0.61	0.53	0.02	0.01	0.54	0.78
LBSR	-0.21	-0.19	0.52	0.12	0.31	0.27	-0.58	-0.31
P	0.44	0.48	0.04	0.66	0.25	0.32	0.22	0.27
GDR	-0.44	0.60	-0.44	-0.07	-0.60	0.41	-0.29	-0.47
P	0.09	0.01	0.09	0.80	0.01	0.13	0.29	0.07

[a] OMBD - Organic matter bulk density
LBBD - Leaf blade bulk density
SBD - Stem bulk density
DMBD - Dead matter bulk density
LBSR - Leaf blade:stem ratio
GDR - Green:dead matter ratio.

Table A51. Correlation coefficients and probabilities (P) among eating behavior measured as bite size (BS), biting rate (BR), grazing time (GT), intake (INT) and sward characteristics[a] of the whole and top 20 cm of Pensacola bahiagrass

	Whole sward				Top 20 cm sward			
	BS	BR	GT	INT	BS	BR	GT	INT
OMBD	0.18	0.17	-0.15	0.09	0.19	0.08	-0.15	0.15
P	0.49	0.78	0.58	0.97	0.50	0.77	0.59	0.58
LBBD	0.15	0.04	0.23	-0.03	-0.42	-0.28	0.23	-0.25
P	0.60	0.88	0.42	0.89	0.11	0.30	0.42	0.36
SBD	0.13	0.22	-0.07	0.21	0.14	0.16	-0.06	0.32
P	0.62	0.41	0.98	0.45	0.61	0.55	0.83	0.24
SDE	0.14	0.01	-0.16	-0.06	0.15	-0.06	0.27	-0.14
P	0.61	0.95	0.55	0.83	0.60	0.92	0.33	0.62
LBSR	-0.17	-0.13	-0.05	0.12	0.15	-0.06	0.21	-0.14
P	0.52	0.61	0.87	0.68	0.86	0.76	0.45	0.62
GDR	-0.05	-0.09	0.10	0.11	0.03	-0.12	0.15	0.17
P	0.86	0.76	0.71	0.70	0.91	0.65	0.59	0.55

[a] OMBD - Organic matter bulk density
LBBD - Leaf blade bulk density
SBD - Stem bulk density
DMBD - Dead matter bulk density
LBSR - Leaf blade:stem ratio
GDR - Green:dead matter ratio.

Table A52. Correlation coefficients and probabilities (P) between esophageal extrusa contents of in vitro organic matter digestibility (EIVOMD), crude protein (ECP) and neutral detergent fiber (ENDF) and in vitro organic matter digestibility (IVOMD), crude protein (CP) and neutral detergent fiber (NDF) in the whole and top 20 cm of Floralta limpograss swards

	Whole sward			Top 20 cm sward		
	IVOMD	CP	NDF	IVOMD	CP	NDF
EIVOMD P	0.90 0.01	-	-	0.93 0.01	-	-
ECP P	-	0.44 0.10	-	-	0.48 0.06	-
ENDF P	-	-	0.44 0.10	-	-	0.50 0.05

Table A53. Correlation coefficients and probabilities (P) between esophageal extrusa contents of in vitro organic matter digestibility (EIVOMD), crude protein (ECP) and neutral detergent fiber (ENDF) and in vitro organic matter digestibility (IVOMD), crude protein (CP) and neutral detergent fiber (NDF) in the whole and top 20 cm of Pensacola bahiagrass swards

	Whole sward			Top 20 cm sward		
	IVOMD	CP	NDF	IVOMD	CP	NDF
EIVOMD P	0.68 0.01	-	-	0.74 0.01	-	-
ECP P	-	0.73 0.01	-	-	0.80 0.01	-
ENDF P	-	-	0.50 0.05	-	-	0.56 0.02

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BIOGRAPHICAL SKETCH

Valeria was born on May 22, 1953, in Vicosa, Minas Gerais, Brazil. She is daughter of Myrthes and Cid, and is married to Kepler and has two daughters, Rayanne and Raysla, and one son, Igor.

She received the degree Engenheiro Agronomo from the Universidade Federal de Vicosa in 1974. She received the Master of Science degree in animal science from Universidade Federal de Vicosa in 1976, and the same year joined the staff of the Centro Nacional de Pesquisa de Gado de Corte of the Empresa Brasileira de Pesquisa Agropecuaria (EMBRAPA), working in the area of ruminant nutrition.

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I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

John E. Moore

John E. Moore, Chairman
Professor of Animal Science

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

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